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Contract No. Nonr-1675(00)

DUCTED PROPELLER ASSAULT TRANSPORT

Design Report

Report No. D181-945-002

15 May 1956

BELL *Aircraft* CORP.

[redacted]

This document has been reviewed in accordance with OPNAVINST 5510... declassified ... Date: 7/31/56 W. C. Fortune By direction of Chief of Naval Research (Code 461)

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REPORT NO. D181-945-002

DUCTED PROPELLER ASSAULT

TRANSPORT STUDY

DESIGN REPORT

DATE 15 May 1956

[redacted] 56AA 37293

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AFFIX TO DOCUMENT

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FOREWORD

Contract Nonr-1675 (00) was awarded to Bell Aircraft Corporation by the Office of Naval Research under sponsorship of the Army Transportation Corps. This is one of a series of five study contracts let to investigate the application of various schemes to the design of Vertical Take-off and Landing (VTOL) or Short Take-off (STO) Assault Transport Aircraft.

The particular field of investigation at Bell Aircraft is the application of ducted propeller propulsion systems to the design of aircraft capable of performing the Assault Transport mission. The results of the investigation are presented in the following listed reports:

TITLE	REPORT NUMBER
Summary Report	D181-945-001
Design Report	D181-945-002
Survey of the State of the Art	D181-945-003
Performance	D181-945-004
Stability and Control	D181-945-005
Duct and Propeller Analysis	D181-945-006
Preliminary Structural Analysis	D181-945-007
Standard Aircraft Characteristics	D181-945-008

This document has been reviewed in accordance with OPNAVINST 5510.17, paragraph 5. The security classification assigned hereto is correct.

Date: 7/30/56

By direction of
Chief of Naval Research (Code 466)

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I. SUMMARY

The material presented herein comprises the design studies which were accomplished in fulfillment of the work statement of Contract Nonr 1675(00), Ducted Propeller Assault Transport Study. The calendar period of 1 May 1955 through 15 May 1956 is the elapsed time through which the contract extended and during which the presented work was performed.

In general presentation of the material in this report conforms with the chronological order of the studies as they were accomplished.

General and specific studies of drive systems and ducted propeller arrangements are presented. Then, initial exploratory configuration studies were made to evaluate the practicability of various duct and transmission arrangements.

A preliminary study configuration (Twin Duct) was selected in order to obtain integrated aerodynamic, structural and design data and experience upon one specific aircraft. The results of the design studies performed on this airplane are presented and served as the basic point of departure for the specific configuration design studies that followed.

With the background from these previous studies, a configuration was evolved which appears to approach the solution for a superior assault transport aircraft. A fairly extensive preliminary design analysis is presented for this aircraft configuration.

II. INTRODUCTION

The work statement for the present Contract Nonr 1675(00) states that configuration design studies will be accomplished to investigate the practical application of ducted propeller units to assault transport aircraft. Design studies were designated in several broad categories as follows:

1. Determination of practical systems of power transmission to the ducted propellers.

2. Conduct introductory studies of assault transport configurations utilizing the results of the propulsion system studies.

3. Accomplish a brief preliminary design of a promising configuration for an assault transport capable of meeting the requirements designated for the study.

With exception of several additional items, the design work has generally followed the above-listed work outline. These additional items were:

4. Design aspects of the safety considerations for VTOL aircraft.

5. Supporting design work necessary for assisting the wind tunnel ducted propeller model testing program which the University of Wichita is conducting under a separate ONR contract.

The amount of effort available to the configuration studies under the contract was somewhat restricted since the major emphasis in the program was, of necessity, placed on the investigation and determination of the ducted propeller units, which were the single most important and relatively undefined basic component of the aircraft design. However, the large portion of the design work accomplished was supported by additional funds which were supplied by the Bell Aircraft Corporation.

III. PROPULSION SYSTEM DESIGN STUDIES

A. General

At the onset of the study, it was evident that the major unknown quantity in this study of a practical assault transport aircraft was the duct-propeller propulsion system. A limited amount of design data was available from the original brief studies which preceded the contract period.

It was realized that the size and weight of the aircraft is, to a large extent, determined by the propulsion system which is necessary to provide the VTOL capability. Therefore, it was necessary to determine the lightest possible system consistent with reasonable development, fabrication and maintenance of the components.

The turbine-propeller powerplant is considered necessary to the success of any ducted propeller VTOL transport, and any improvement in the engine characteristics is immediately reflected in better aircraft performance or increased payload capability or allows the design of a lower gross weight aircraft. The requirement of take-off operation at 6000 feet altitude on a 95°F day is also a factor which must be considered in the selection of the power plant.

The approach to the design of the propulsion system was shaped about the progress of the aerodynamic analytical studies of ducted propeller units. While the basic investigations were in progress, design studies of an exploratory nature were conducted to obtain trend data on the variation of system characteristics. Then, as soon as initial design data became available, a preliminary study configuration was selected as the object of more detailed investigations. The design knowledge gained from the propulsion system work on this preliminary configuration was then applied on the design studies of other configurations which eventually resulted in the final aircraft system arrangement.

B. Propeller Drive System Study

The original studies of the ducted propeller aircraft were based upon a ducted propeller units at each wingtip. However, the results of a brief parametric study of possible drive systems showed a decrease in total propulsion system weight when a number of smaller ducted propeller units of equivalent total area is substituted for the twin ducts. An aircraft and drive system arrangement was briefly investigated (Fig. 1) in which the duct units were grouped in four pairs, a pair at each wingtip and a pair under each inboard wing panel. This study resulted in a complex system of gear boxes and interconnecting shafting, and it was concluded that the problems encountered in designing, developing and maintaining the system would more than offset the relatively small weight saving derived.

Twin Duct System Design

A preliminary two duct configuration was established to be used as a basic design for aerodynamic analyses of a typical ducted propeller transport. Since it was desirable to obtain design data on a twin duct propulsion system, the same configuration was also adopted as the subject for an

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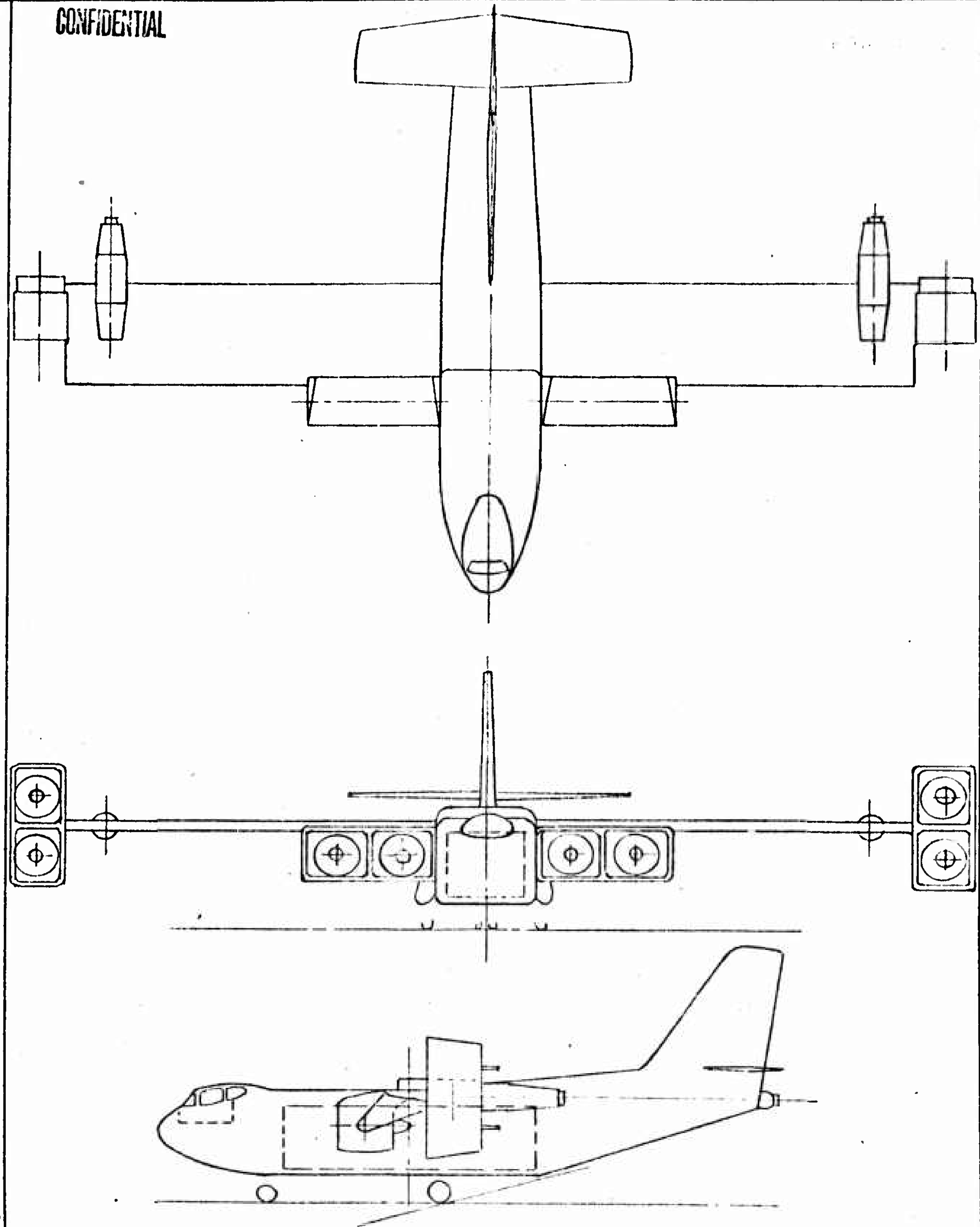

FIGURE 1 - Power Plant System Design Configuration

1" = 200"

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intensive design study. The general arrangement of this study configuration is presented in Fig. 2.

The duct and propeller design requirements established by the Aerodynamic analyses were integrated into the drive system study. The propeller diameter was established by practical ground clearance requirements and the propeller blade tip speed set by aerodynamic considerations determined the propeller rotational speed. The powerplant selected for the configuration was the Wright T49 turboprop engine with a basic shaft speed of 8000 rpm. The weight of the interconnect shafting can be held to a minimum by transmitting the power at a high rpm. Therefore, the standard T49 reduction gearing was replaced by a single one to one ratio spiral bevel pair which would transmit the power to the outboard locations through the lightest practical shafting system. A section view of the engine gear box appears in Fig. 3. The unit was designed for assembly on the basic engine with the reduction gear box removed. A sprag type overrunning or freewheeling clutch is installed to allow single engine operation of both propeller units through the interconnect shaft (bottom of gearbox). Spherical couplings allow angular motion of the shafts with respect to the gearbox thus preventing extraneous distorting loads on the gear casing.

The complete propeller drive system is presented in a sectional view on Fig. 4. The power is transmitted by the torque tube into the duct gear box which reduces the speed through a right angle bevel pair and a single stage of planetary gearing to the desired propeller speed. The system was

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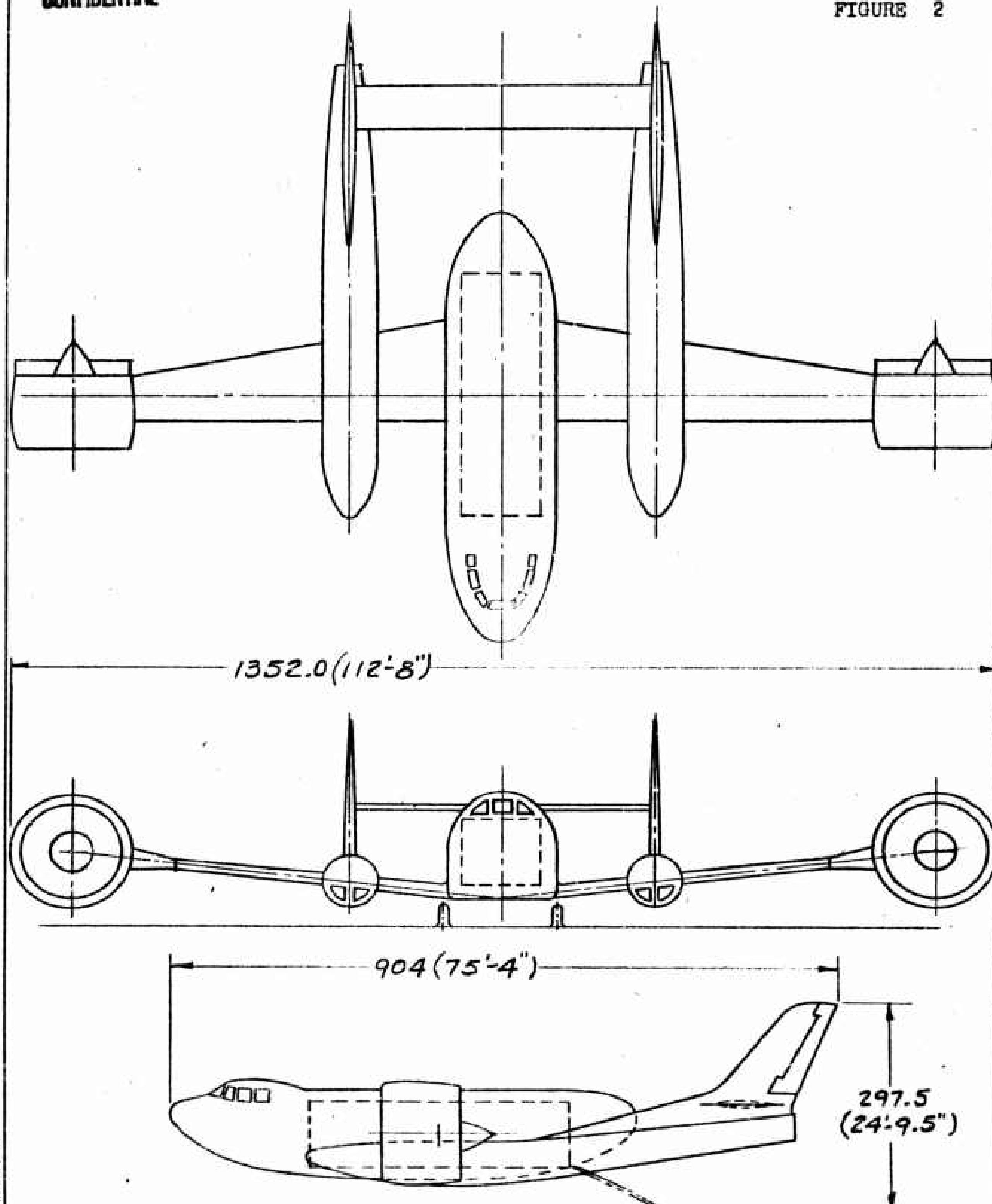
FIGURE 2



PRELIMINARY STUDY CONFIGURATION
D181-960-010

1/200 SCALE

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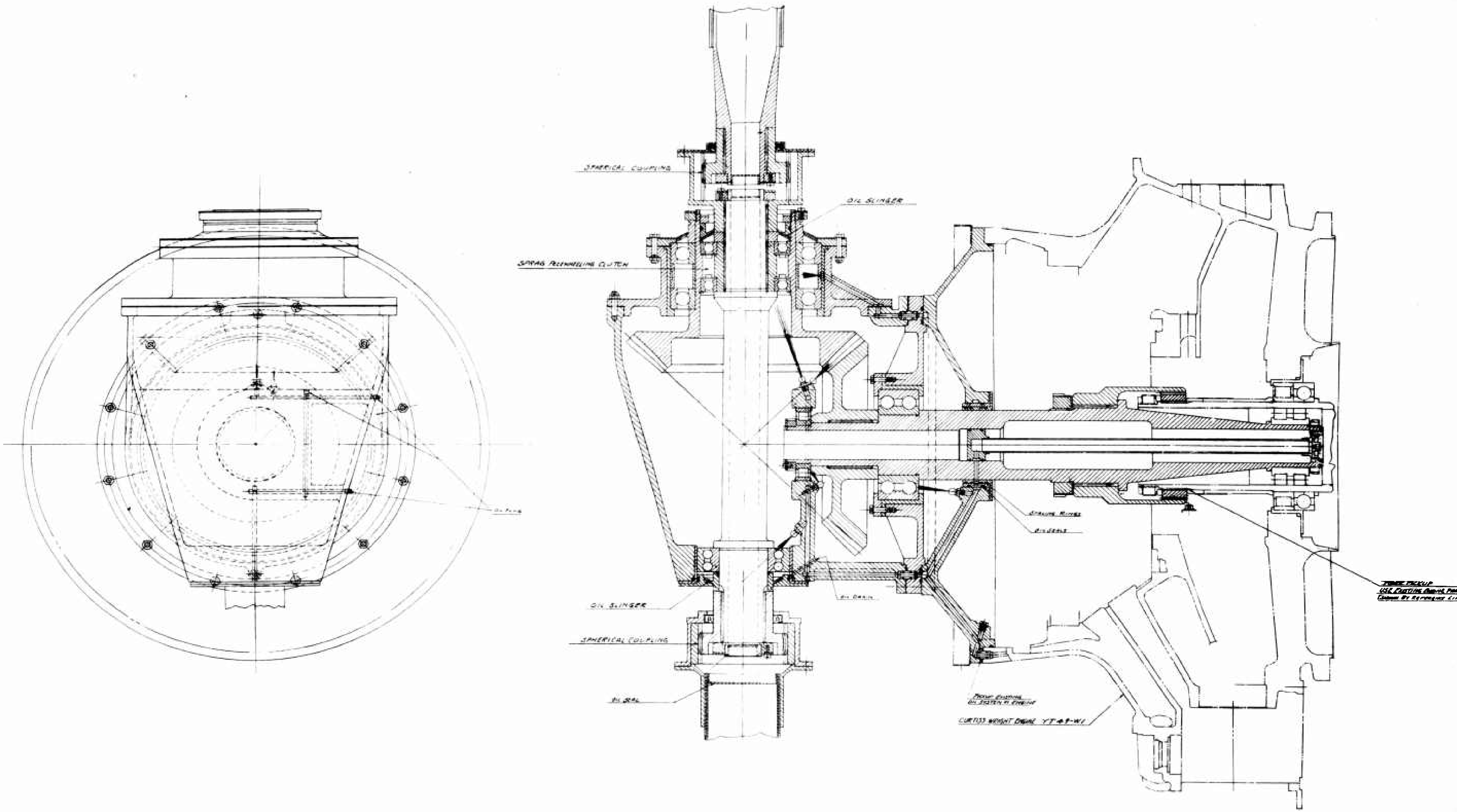

Figure 3. Dwg. No. D181-960-006: T-49 Engine Gear Box (Twin Duct)

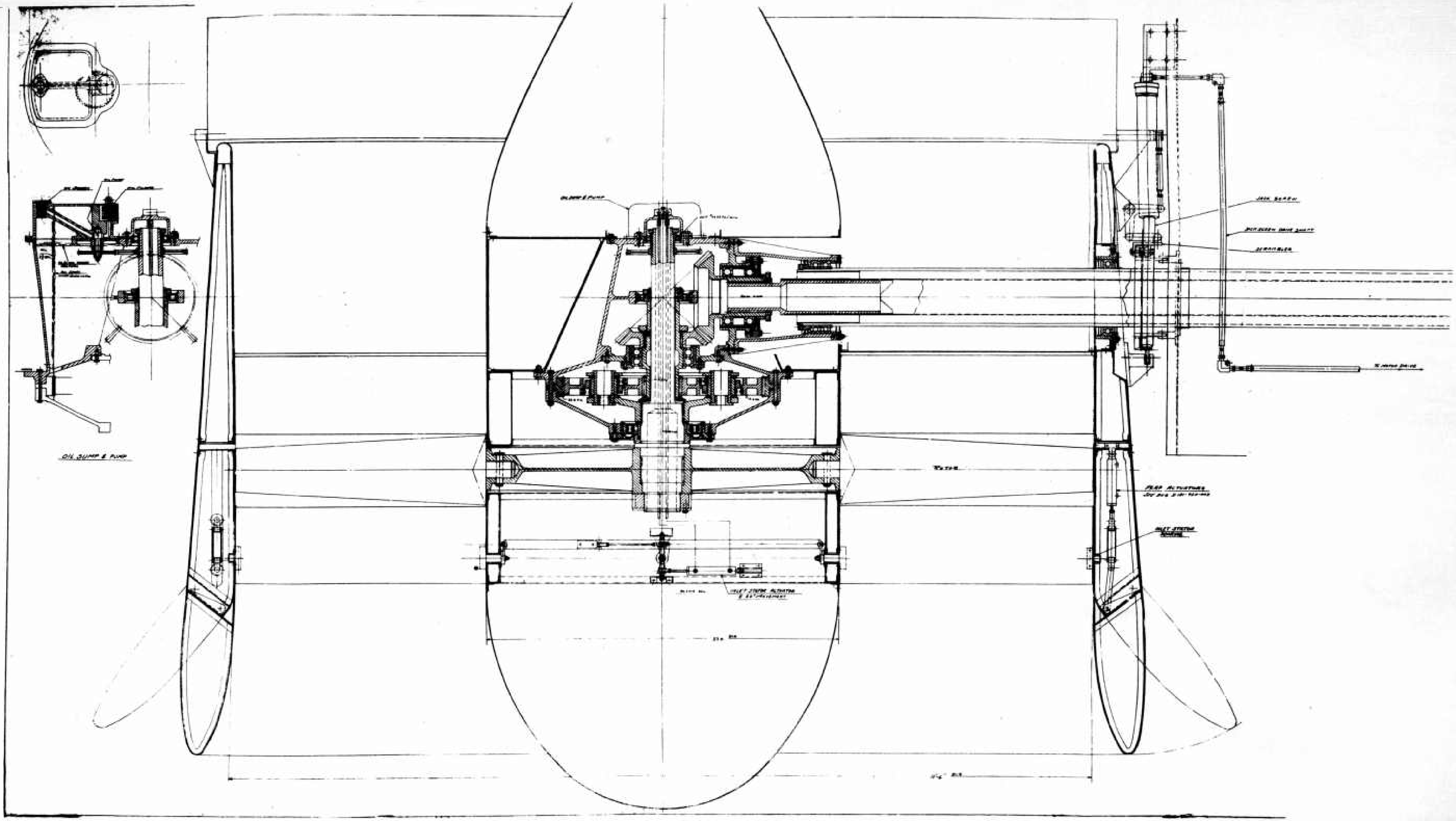

Figure 4. Dwg. No. D181-960-003: Twin-Duct Propeller Drive System (Sheet 1 of 2)

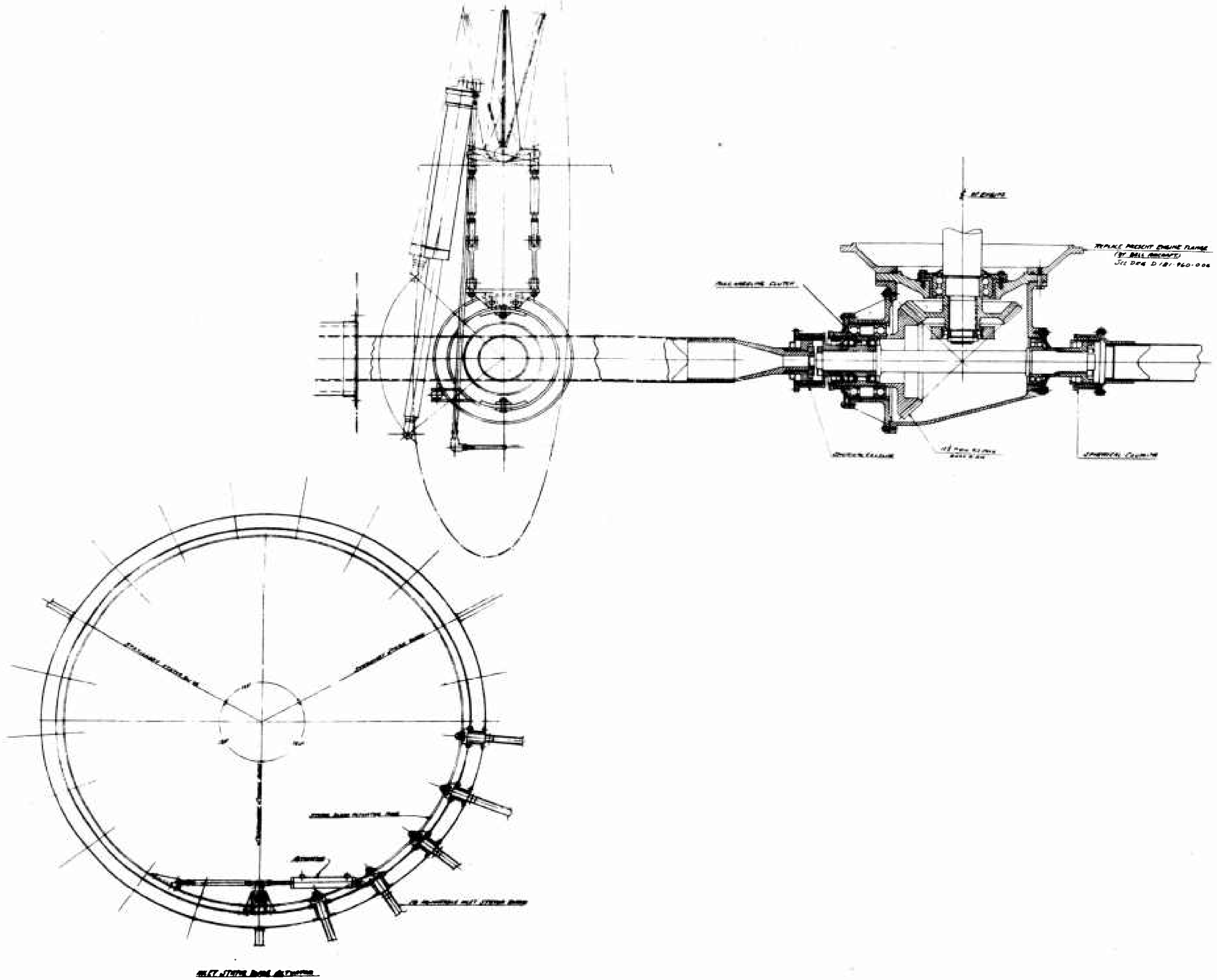

Figure 4. Dwg. No. D181-960-003: Twin-Duct Propeller Drive System (Sheet 2 of 2)

designed in fairly complete detail in order that reasonable weight estimates could be obtained for typical drive systems.

Four Duct System Design

In order to round out the picture of powerplant system design, several four duct configurations were studied. In these arrangements a pair of coupled engines were used to drive an outboard propeller and a single engine drove a mid-wing mounted duct (Fig. 5). The six engines were not interconnected mechanically since a catastrophic situation does not accompany a single engine failure in this case. In these studies, as before, it was found that appreciable weight savings were realized by transmission of power at the basic engine speed and that the number of gear boxes in the system should be held at the lowest practical minimum.

The simplest and most direct approach to the drive system problem was found to be the conventional engine gear box mounted propeller. Although there are certain complications due to location of the engines in the duct centerbodies, the drive system weight and complexity are reduced to the practical minimum. It was found that a coupled engine could be installed in the outboard duct centerbody and that a single engine would drive the inboard propeller. These designs are referred to as the four duct tilting engine configurations, an example of which is seen in Fig. 6.

C. Duct Design and Inlet Flaps

The basic duct section was chosen to be a constant area channel from the propeller station back to the duct exit. However, the results of the

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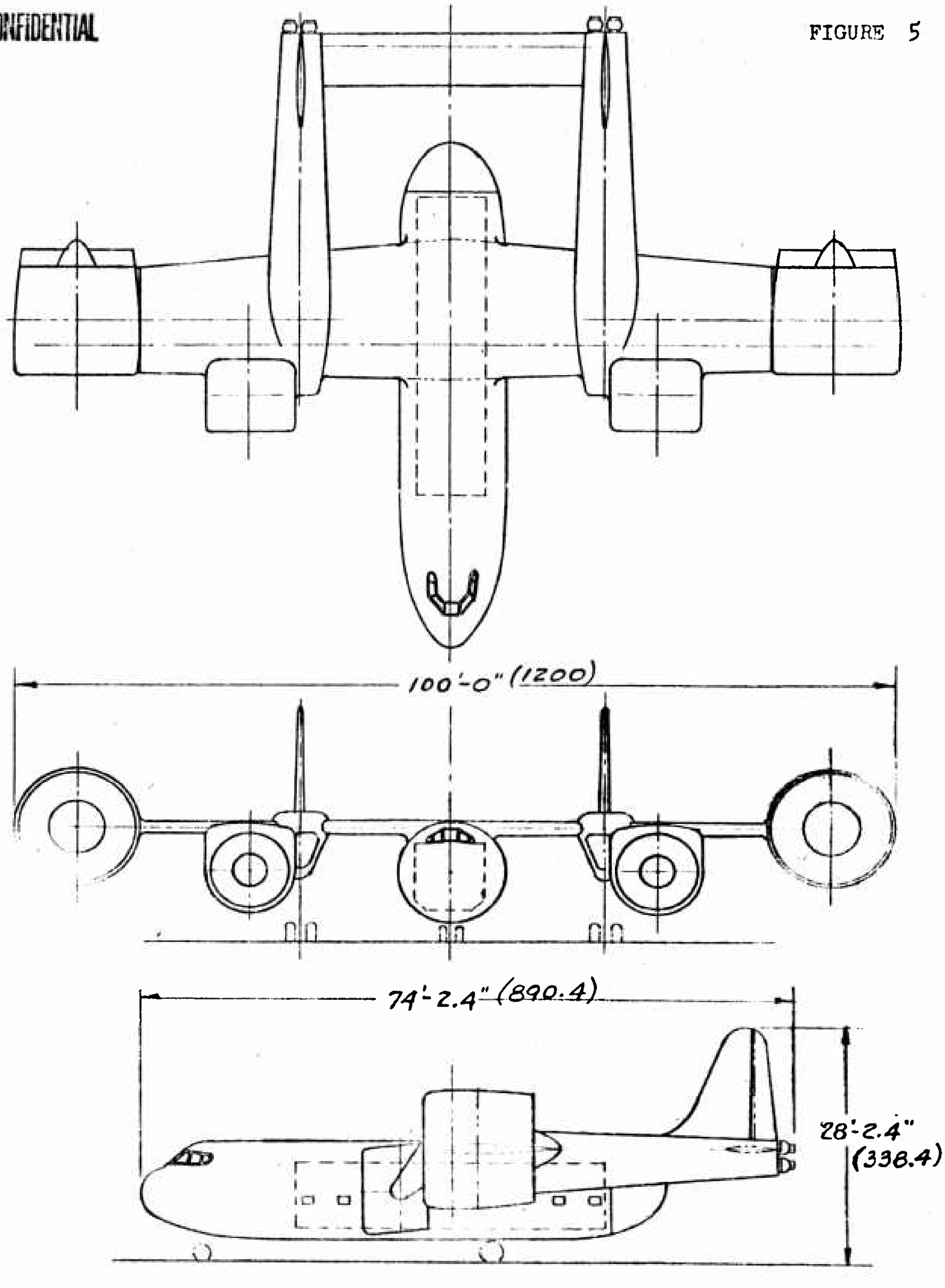
FIGURE 5



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FOUR-DUCT, TWIN BOOM CONFIGURATION

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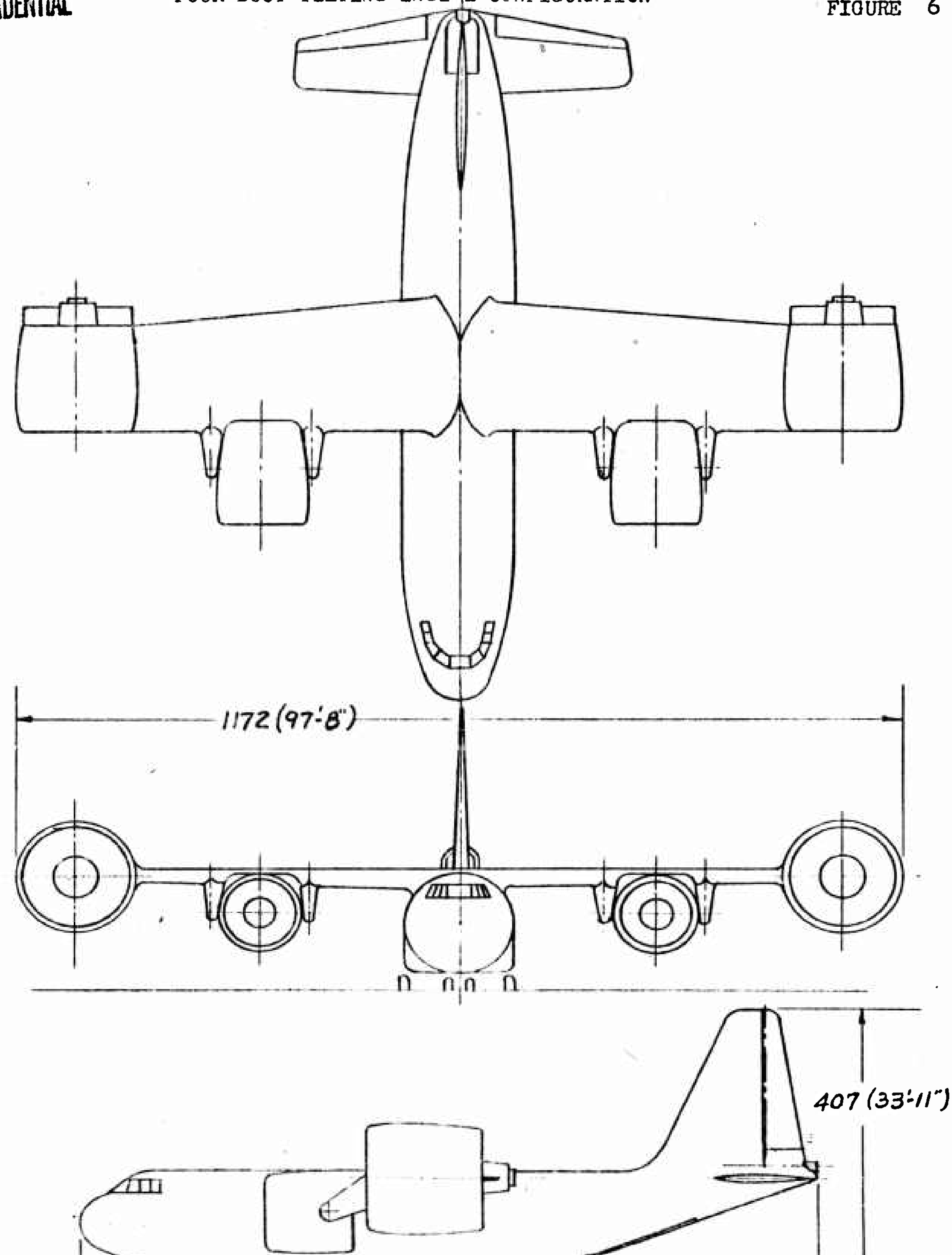
FOUR-DUCT TILTING ENGINE CONFIGURATION

FIGURE 6



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aerodynamic studies have indicated the necessity of variable duct inlet area to maintain propeller efficiency through the required range of forward flight speeds. The design study of this feature for the full size duct has been based upon the concept of modifying the leading edge of the duct profile.

The ideal inlet shape for the duct at static operating conditions is the bell-mouth or nozzle contour. For flight operation the most efficient inlet will have a thin lip forming a non-converging duct or even a diffuser section. To obtain efficient propeller operation at static conditions and during forward flight, it may be necessary to provide a variable position leading edge to form suitable inlet shapes at the various operating conditions.

Initial studies showed the impracticability of flaps which could be folded back against the exterior surface of the duct chiefly because of the incompatible curvature of the flap segments and the duct surface.

The feasibility of retractable flapped leading edge extensions was briefly studied with the result that a tracked flap extension system similar to a Fowler flap device was designed.

A third method was investigated using the simple flapping of the duct leading edge ahead of the propeller. This has proved to be the least complex and most practical of the methods investigated, and will be used if the aerodynamic performance of such an inlet is acceptable. The flap segments are simultaneously pushed out by means of several actuators located within the duct profile. A positive locking system is used to hold the flaps closed in event of power loss.

Fig. 7 shows the practical variable inlet duct design which has resulted from the study. The duct leading edge is opened out to form a modified bell mouth inlet when the system is operating at static take-off conditions. After transition into forward flight the flaps fold in to form the high speed low drag duct contour necessary for good forward flight performance.

D. Duct Rotation System.

A typical system devised for rotation of the ducted propeller units is presented in Fig. 8. Although it is shown for a four duct installation, the basic element of coordination is evident. It is imperative that all the ducts move in unison so that no unusual thrust conditions will occur during duct rotational phases. A standby system will operate from the auxiliary power source in case of a primary system failure of any sort.

E. Powerplant Selection.

In the course of the design studies, turboprop engines in the 3000 HP to 10,000 HP range were considered in specific configurations. Engines that were considered included the T54, T56, T49, RB109, and Allison 550B1 turboprops. Advanced types such as the RB109 and the Allison 550B1 which will be available in the pre-1960 era have proved to be very good for application to the ducted propeller transport design.

Reduction Gear Design.

In general, the propeller speeds suitable for ducted propeller operation are higher than the corresponding bare propeller required rpm. In those

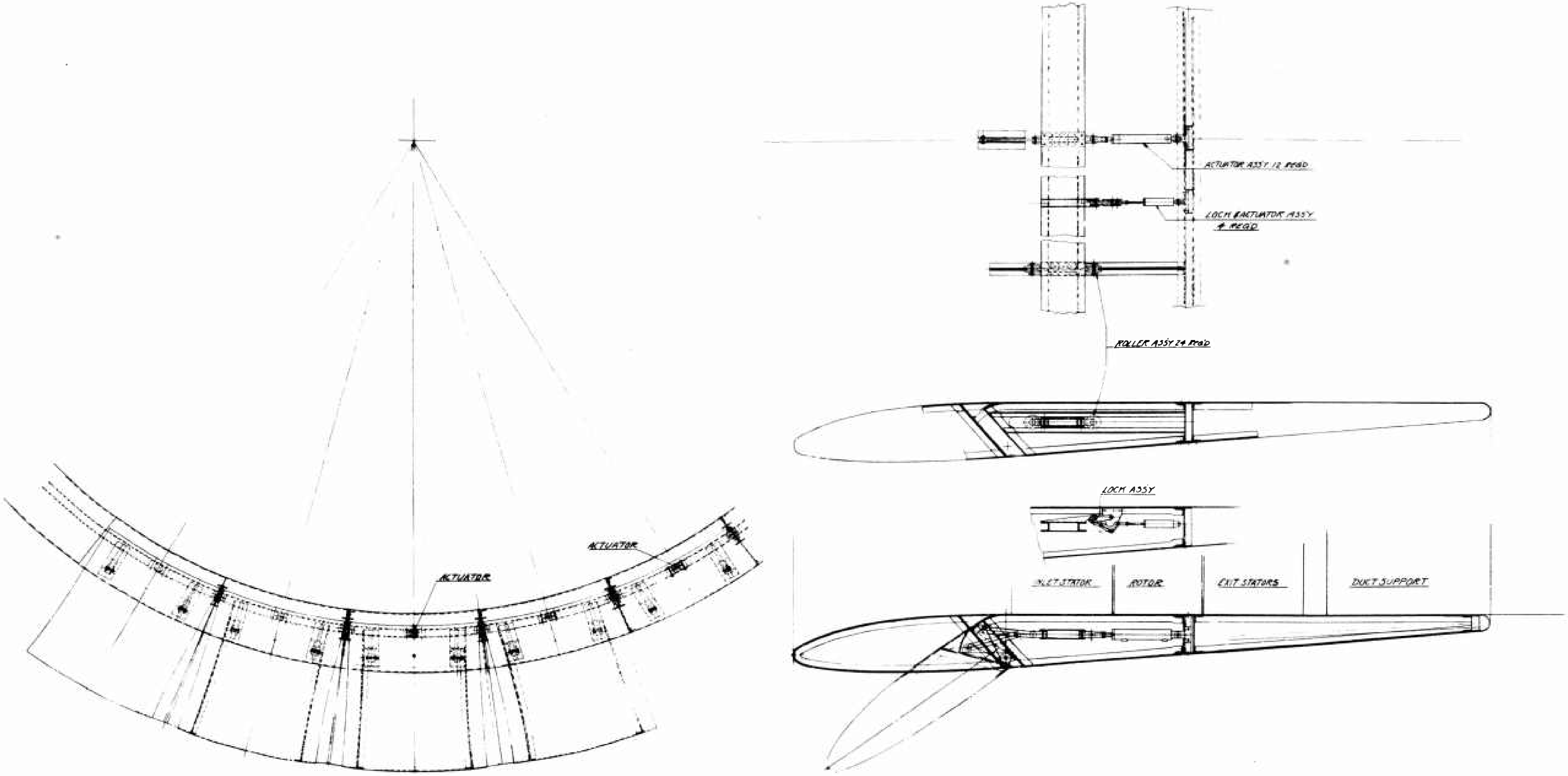

Figure 7. Dwg. No. D181-960-002: Duct Leading Edge Flap System

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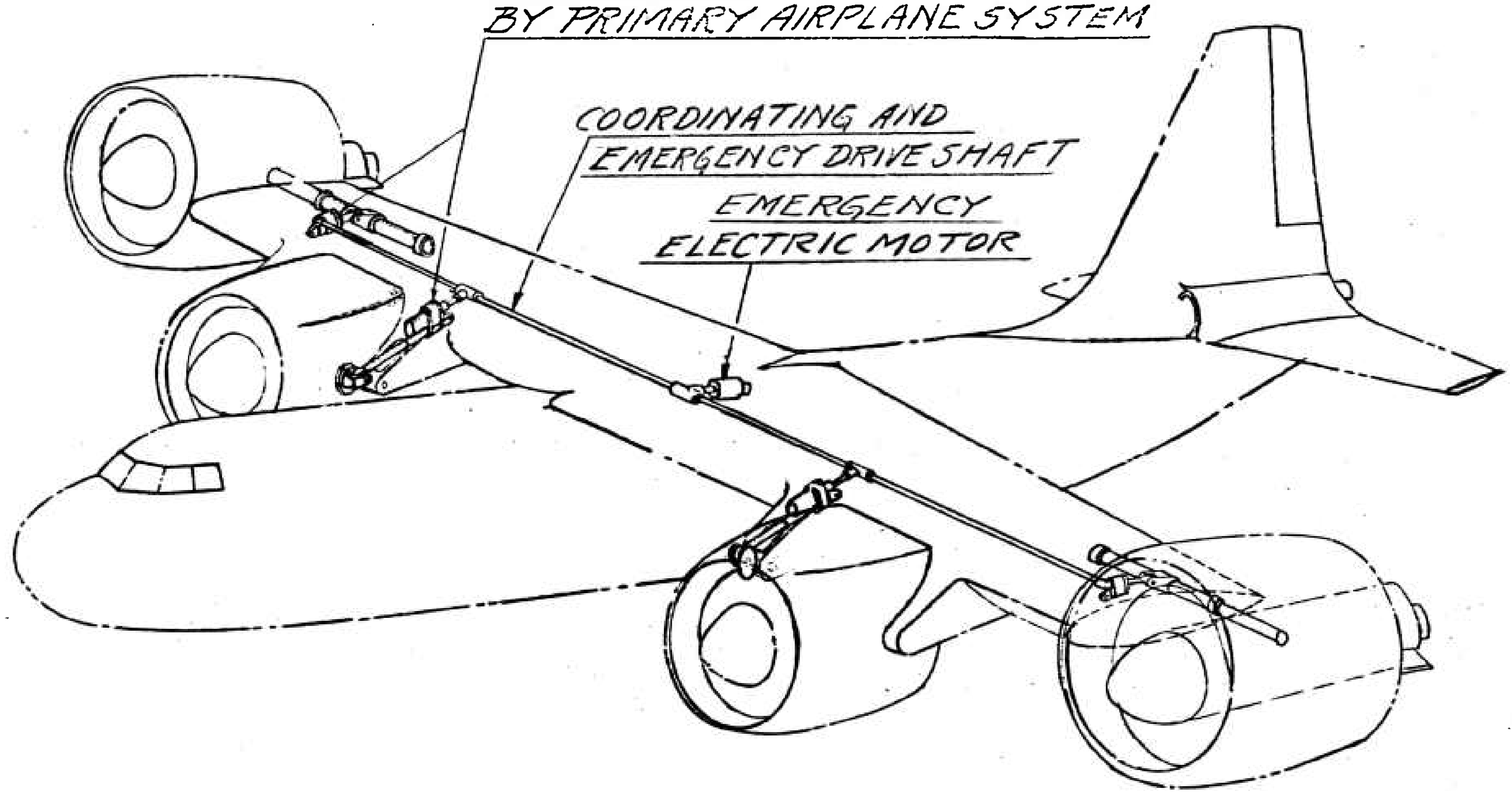

FIGURE 8
DUCT ROTATION SYSTEM

EMERGENCY DRIVE & DUCT ROTATION SYSTEM
MEDIUM CARGO TRANSPORT V.T.O.L.
D181-960-020 C.M. Sprazza 3/23/53

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applications where the propeller is mounted directly to the reduction gear outlet shaft, the weight of the gearing will be lighter than the normal lower output speed system. For simplicity and a measure of conservatism the reduction gear weight has been assumed equal to the basic engine gear box weight. In those instances where two engines are coupled to drive a contra-rotating propeller, the basic engine reduction gear box weight is again used in the estimations of the redesigned gear box.

For those configurations where the power is shafted from the engine to separate propeller locations, it was determined that the highest practical shaft speed should be used to minimize weight. This indicates that the normal engine reduction gear box should be removed and replaced by a simple one-to-one ratio right angle spiral bevel gear set.

The development of reduction gear systems is necessary in both of the types mentioned above.

Engine Operation.

The expected operational areas for the aircraft include locations at 6000 ft. altitude and 95°F temperature. Under these ambient conditions, the standard sea level ratings of turboprop engines will be reduced by about one-third. It has been found that it is practical to recover full sea level performance by injection of water into the engines (Ref. 1). This has been confirmed in discussions with engine manufacturers. For this study it has been assumed that the engines will be equipped with a water injection system to recover sea level power under hot day and altitude take-off conditions. It may be mentioned here that water injection augmentation systems are standard equipment on many turbojet and turboprop engines in operation today.

The ducted propeller units have been designed to deliver take-off thrust sufficient to perform normal VTOL operations at 6000 ft. and 95°F. using the sea level power recovered by the water injection. Sea level thrust available from this system will be about 10% greater due to the increased density of the air through the ducted propellers at the lower altitude and temperature.

The later stages of the study showed decided advantages for the center-body mounted turboprop engines in those configurations known as the tilting engine types (Fig. 6). The advantages gained in weight and complexity are partially offset by the additional engine development entailed. The tilting engine concept will require the engines to be operated in all positions from the normal horizontal position through the vertical or zero to ninety degrees. This will present additional lubrication problems which will require development of a suitable system to permit operation of the engine under these new conditions. Again it must be mentioned that several turbine engines have already been modified to operate under the same conditions as required in the present case. The problem will be somewhat relieved by the limited time of operation in the vertical and intermediate positions. The engine manufacturers have been made aware of the possible changes in the mode of operation. It would be advantageous to introduce the additional operational requirements early in the development of any new engine which could be applied to the selected aircraft designs, since the features could be more easily incorporated in the development stages than in the production stages of the engine.

IV. GENERAL CONFIGURATION STUDIES

A. General.

The major design factors which were considered in the configuration studies were contained in the requirements set out as the ground rules at the inception of the study. The aircraft size in this case was determined by the basic payload required and the cargo compartment cross-section dimensions desired. These were 35 airborne troop weighing 8000 pounds or equivalent cargo to fit the 8 ft. by 9 ft. compartment dimension.

The vertical take-off requirement exerted a great influence upon the design concepts. First, the thrusting units must be arranged so that the resultant should pass through the airplane center of gravity. Secondly, this requirement will allow the use of higher wing loadings which are better suited to the airplane cruise conditions. Also, the need for flaps to increase lift coefficient at landing is eliminated, thus leading to more efficient and lighter wing structure.

The obvious safety requirement of airplane attitude control during partial power failure during hovering influenced the propulsion system design so that uncontrollable moments would not be introduced under these conditions.

In addition, the operation of the aircraft as a short take-off vehicle was considered from the outset in the concept and design of the landing gear and aircraft structure.

B. Twin Duct Configuration.

In the early stages of the study a preliminary two-duct configuration was established to be used as a basic design for aerodynamic analyses of a typical ducted propeller transport aircraft. The basic propulsion units for this design were established in the initial aerodynamic ducted propeller studies. Preliminary aerodynamic aircraft performance analyses were to be conducted for this configuration. The design parameters chosen for the design were 48,000 lb. gross weight, 8000 lb. payload, and 15,000 lb. fuel. A general arrangement of the configuration is presented in Fig. 9. It must be emphasized that this configuration was established as a working tool from which would evolve other more refined and realistic assault transport designs.

As stated previously, this configuration was used as a point of departure for the first aerodynamic studies. It is only reasonable that this configuration was also used as the subject of the first intensive design studies and preliminary structural analyses. It was appreciated that the configuration was based upon very rough assumptions, especially with regard to the propulsion and control systems, and that there was a good likelihood of a resulting incompatible design. Nevertheless, the information obtained from an integrated study of a single configuration can be very valuable as basic data in the determination of later more realistic designs.

The description of the propulsion system design study for this aircraft is contained in an earlier section of this report. Two T49 turboprop engines were selected for the powerplants and the power was shafted at high speed to the outboard gear boxes. Freewheeling clutches at each engine gear box and interconnecting shaft insures a division of power to the two propellers.

The initial detailed duct and propeller studies were carried out for this configuration (Ref. 2). A satisfactory aerodynamic design was accomplished and a system using the physical characteristics so determined was designed in

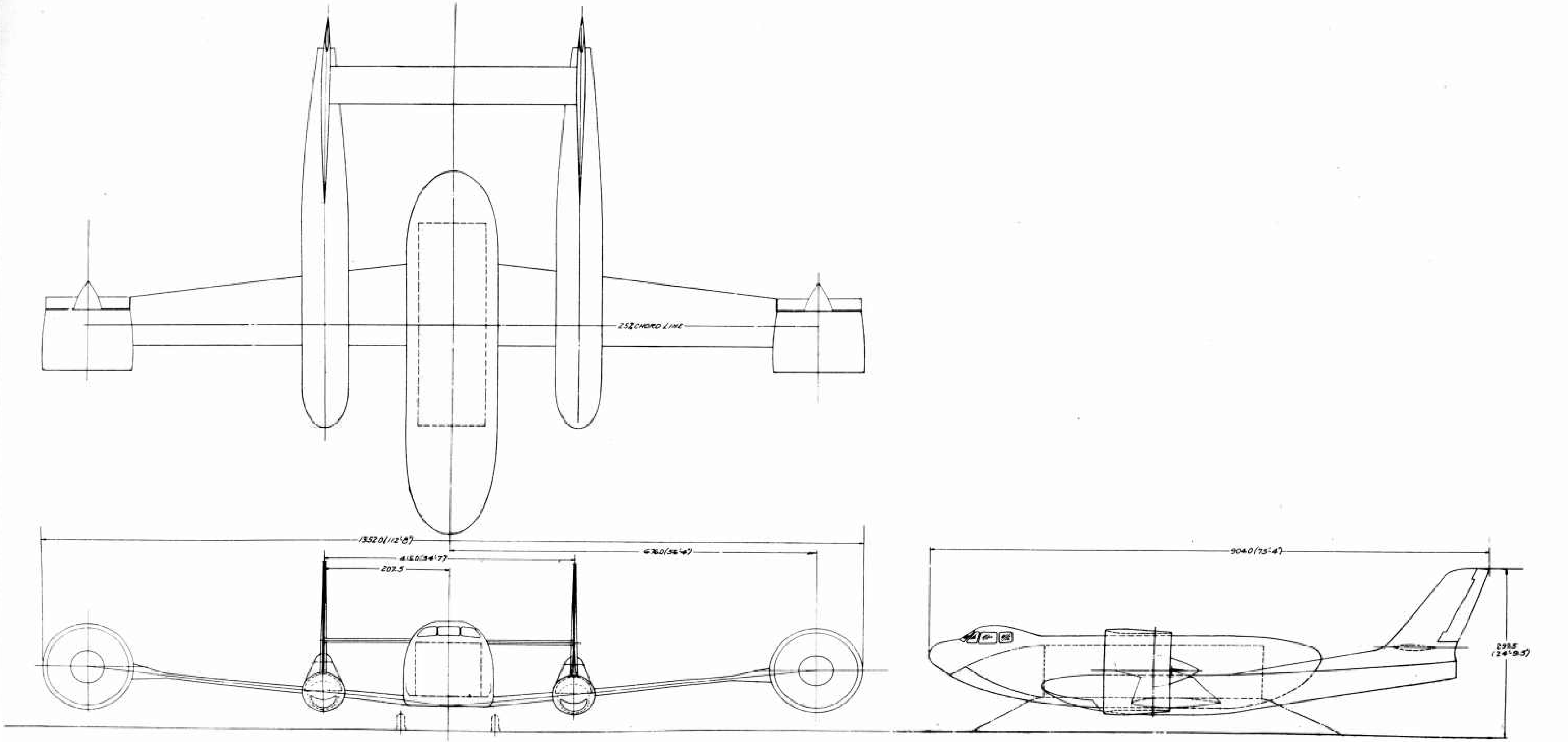

Figure 9. Dwg. No. D181-960-001: Twin-Duct T-49 Configuration

a preliminary fashion (Section III). A tenth scale model of this design was also specified for test in the University of Wichita subsonic wind tunnel. A weight analysis of the full size system which was designed is summarized in Table I. These data are considered to be conservative after comparison with available data on similar items (Ref. 3).

TABLE I

PROPULSION SYSTEM WEIGHTS

Duct Structure (Nacelle Section)		
Outer Shell including Leading Edge Flaps and Actuators		850 lbs.
Center Body Structure		203
Exit Stators		99
Inlet Guide Vanes		136
Support Struts		88
Actuating Mechanisms		60
	Total per side	1436 lbs.
Rotating Components		
Engine Gear Box		486
Shafts		440
Propeller Gear Box		1345
Oil System		75
	Total per side	2346 lbs.

The design study was continued with this propulsion system data and other information gathered from sources. The final weight results are summarized in Table II. The design is not consistent in that the propulsion system was designed for a 50,000 lb. take-off weight and the surfaces and landing gear were also sized for this gross weight. In other words, a compatible design would be much heavier than the 59,000 lb. aircraft which is shown.

TABLE II

WEIGHT ESTIMATE OF TWIN DUCT

PRELIMINARY STUDY CONFIGURATION

Dwg. D181-960-010

		Weight
Wing		3500
Tail		
Horizontal		350
Vertical		600
Body		
Fuselage		3820
Booms		880
Landing Gear		1500
Surface Controls		500
Engine Sections		2000
Ducts for Fan and Wing Tips		2872
Propulsion Group		
Engine Installations - Two T-49's		6980
Gear Boxes and Drives		4692
Engine Accessories		600
Lubricating System		210
Fuel System		462
Engine Controls		30
Starting System		125
Propeller Installation		1930
Auxiliary Power Plant		100
Instruments		175
Hydraulic		300
Electrical		800
Electronics		500
Furnishings		644
Air Conditioning and Anti-Ice		500
	Total Weight Empty	34070
Crew (3)		690
Payload		8000
Fuel		15000
Oil		240
Water-Water Injection		1000
	Total Useful Load	24930
	Gross Weight	59000

C. Four-Duct Configurations.

The twin-duct configuration had been designed around the minimum size cargo compartment to carry the specified 8000 lb. payload. When the aerodynamic performance studies (Ref. 4) showed the increased payload capabilities of STO operation, it was decided that a larger cargo compartment should be used to accommodate the increased STO payloads. Therefore, the aircraft size was somewhat increased in order to obtain a more versitile over-all design.

The estimated gross weight of the larger configuration required a duct diameter for a two-duct configuration which appeared too great to allow an adequate ground clearance angle. It was felt that a four-duct configuration would relieve this situation. Also, the investigation of a four-duct configuration was judged desirable to obtain more information for the general powerplant system design study. The first four-duct configuration studies were based upon propulsion systems in which a pair of coupled turboprop engines drove a large outboard ducted propeller and a single engine of the same type to power the inboard ducts. A typical design based upon the use of the Allison 550-B1 engines is presented in Fig. 10.

The use of six engines occasioned a departure from the basic concepts of two-engine operation. Mechanical interconnecting of the ducts was eliminated since the multiple engine installation allows maintenance of thrust balance by engine power manipulation in cases of single engine failure. That is, the loss of power from one of the Allison 550 units could be compensated by immediate shutdown of the corresponding unit on the opposite wing or by partial reduction of power on the engines on the opposite wing to maintain thrust symmetry of the propeller units. The shaft lengths were kept to the minimum

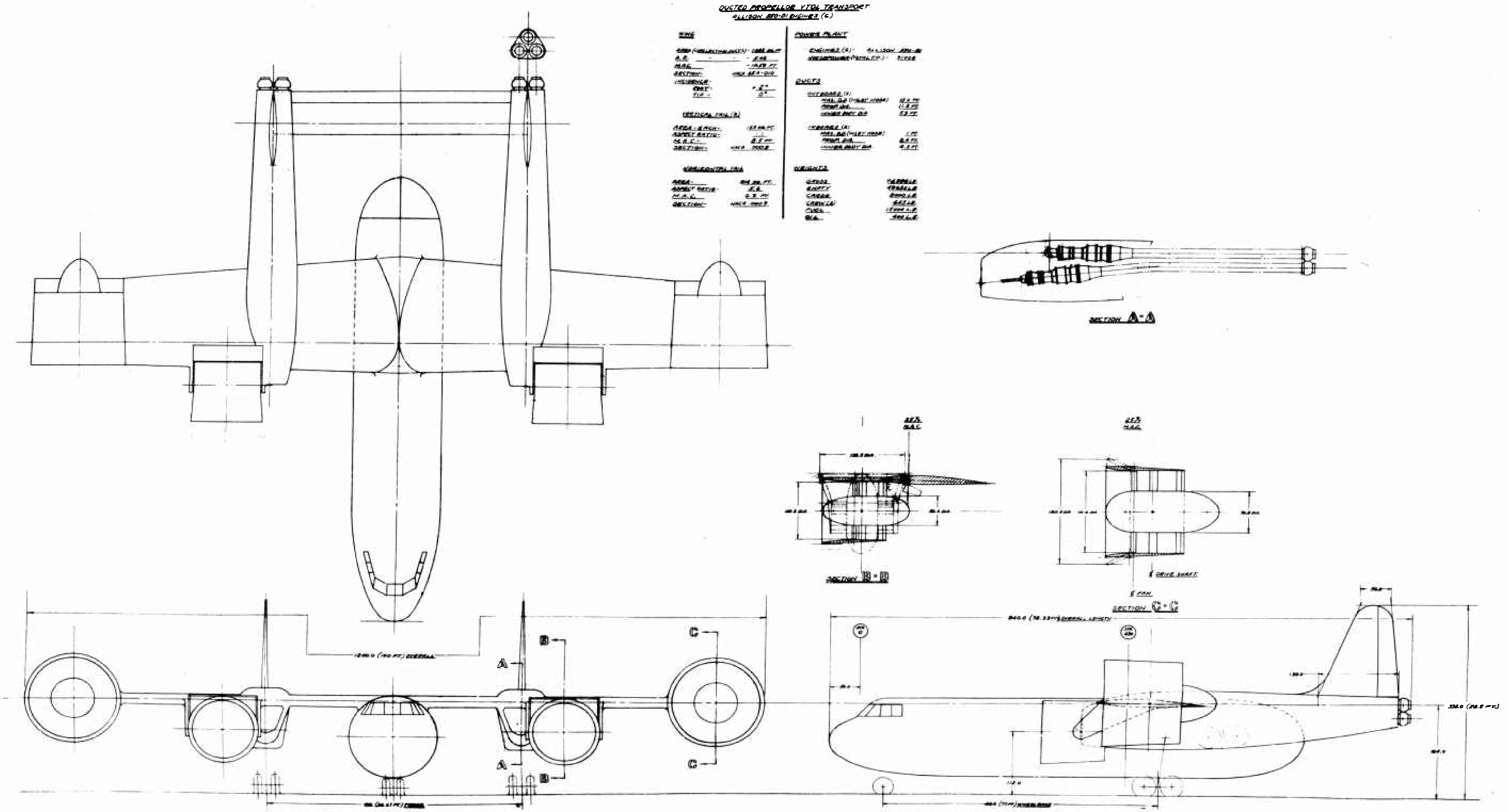

Figure 10. Dwg No. D181-960-011 Twin-Boom Allison 550 Configuration

and the lowest possible number of gear boxes were specified for the configuration. This criteria resulted in a design in which the engines are grouped in nacelles on each wing and the tail pipe extensions give the aircraft a twin boom type of configuration. An estimated weight summary is presented in Table III.

Four-Duct Tilting Engine Configuration.

In the study of four-duct configurations, the concept of propeller units which incorporate the turboporp engine in the duct centerbodies was investigated. One disadvantage of this arrangement is the necessity for the engines to operate at all angles of tilt up to 90°. Another requirement would be the need for an auxiliary reaction control system for hovering and slow speed operation. The advantages of the system are the elimination of shafting and the contribution of the residual jet exhaust to the lifting thrust of the ducted propeller units. Six RB109 turboprop engines are used in this application. The six Westinghouse RB109 engines are located in the duct centerbodies A general view of this configuration appears in Fig. 11, the general arrangement drawing showing the over-all configuration. This was based on a rough weight and balance analysis from which placement of major aircraft components, determination of surface areas, and location of the propulsion units were accomplished. In the course of this work, it was found that the installation of a single General Electric J85 engine in the aft fuselage would be adequate to furnish pitch reaction control during hovering and slow speed flight. The propulsion units were disposed longitudinally so that the resultant thrust vector will act through the airplane center of gravity. A typical military

TABLE III

TWIN BOOM ALLISON 550 ASSAULT TRANSPORT

D181-960-011

Item	Weight
Wing	5400
Tail	
Horizontal	492
Vertical	566
Body	
Fuselage	5175
Booms and Nacelles	3720
Landing Gear	2220
Surface Controls	
Flight Controls	500
Reaction Controls	1000
Engine Section (Duct Around Props)	
Inboard	2780
Outboard	3920
Propulsion	
Engines	9450
Gear Boxes at Engines (2)	2850
Gear Box at Inboard Prop. (2)	2000
Gear Box at Outboard Prop. (2)	2000
Engine Mounts	370
Duct Supports - Inboard	300
- Outboard	500
Rotating Mech.- Inboard	60
- Outboard	100
Lubricating System	195
Fuel System	460
Water Injection System	200
Engine Controls	50
Starting System	150
Propeller Installation - Inboard	1094
- Outboard	1522
Auxiliary Power Plant	80
Instruments	160
Hydraulics (Brakes and Nose Wheel Steer.)	50
Electrical	800
Electronics	500
Furnishings	465
Air Conditioning and Anti-Icing	500
Auxiliary Gear (Jacking, Towing)	25
Total Weight Empty	49654
Useful Load	
Crew (3)	645
Oil - Engines	160
- Gear Boxes	240
Fuel	15000
Water	1297
Payload	8000
Total Useful Load	25342
Total Gross Weight	74996

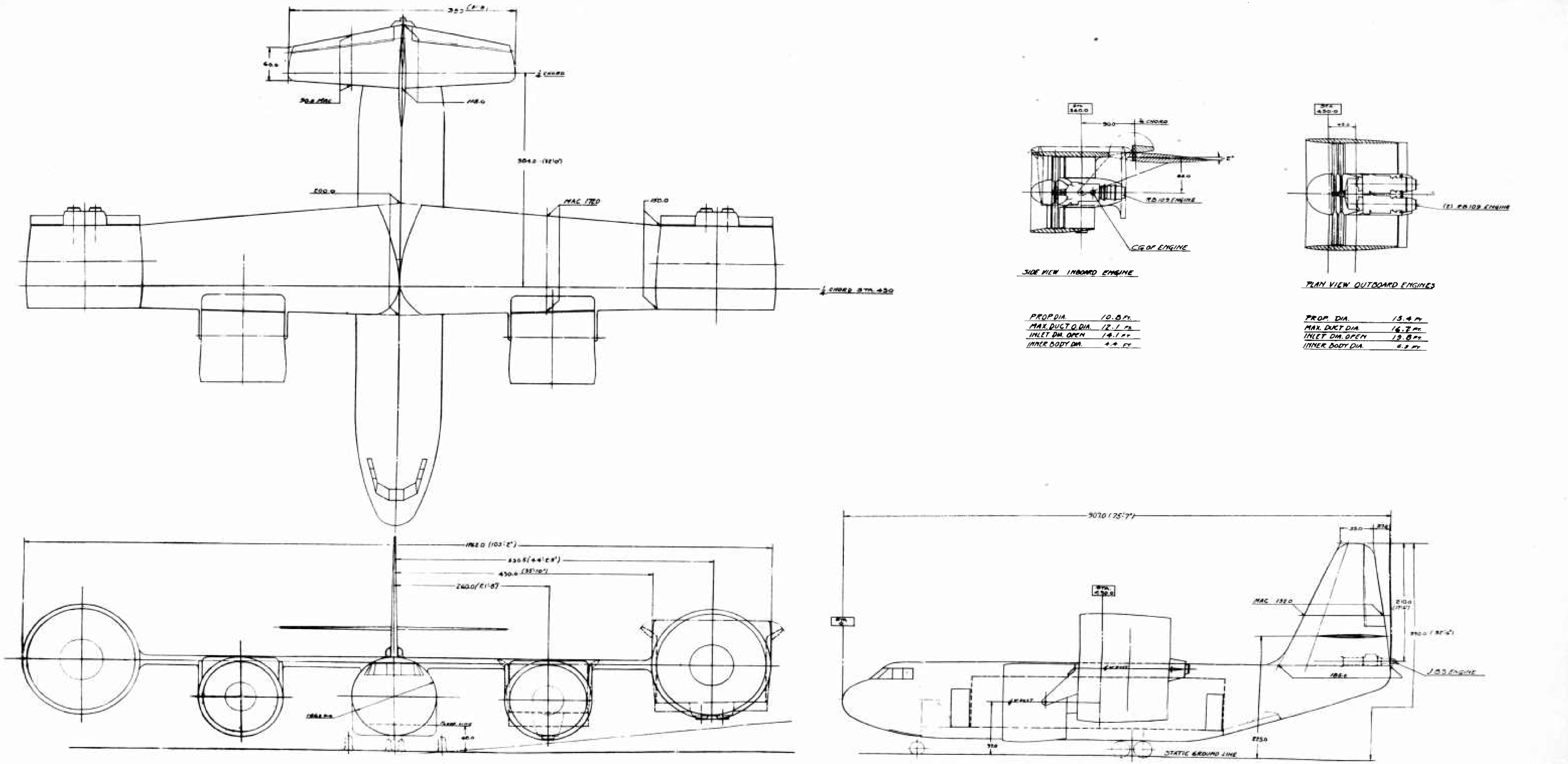

Figure 11. Dwg. No. D181-960-007: Four-Duct RB-109 Tilting Engine Configuration

transport fuselage mounted landing gear arrangement has been considered, and the normal 48 inch cargo compartment floor height is a design feature.

During the general arrangement study the combination of the duct, propellers, and engines was considered. With the engines located in the duct centerbody, the problems of power transmission have been appreciably reduced. For the inboard ducts, the propeller is driven directly from the engine output shaft. In this case, it is assumed that the existing engine gear box has been redesigned to deliver the required propeller RPM. The pivot point for rotation of the unit is located so that adequate ground clearance is provided. The larger outboard ducts are visualized to contain contra-rotating propeller units powered by the two turbine engines in the duct centerbody. The output shafts from the engines drive through a common gear box designed to drive the contra-rotating propellers.

A layout of the inboard duct arrangement is shown in Fig. 12. The method of mounting the engine in the duct is presented using the existing mounting points on the engine casing. The struts which support the duct are cantilevered from the front wing beam. The duct rotation actuating system is installed in one of the struts. The outboard duct arrangement is similar except for the two engine installation in the centerbody and the common gear box to drive the contra-rotating propellers.

During the work on the four-duct configurations, more detailed information was developed for the fixed equipment items and aircraft systems. This data was incorporated in the weight estimate of this configuration and appears in Table IV. The application of the Allison 550-B1 engines to this configuration was undertaken in the natural course of events and was selected as the best representative example as the results of the study. This configuration is presented in the next section of this report.

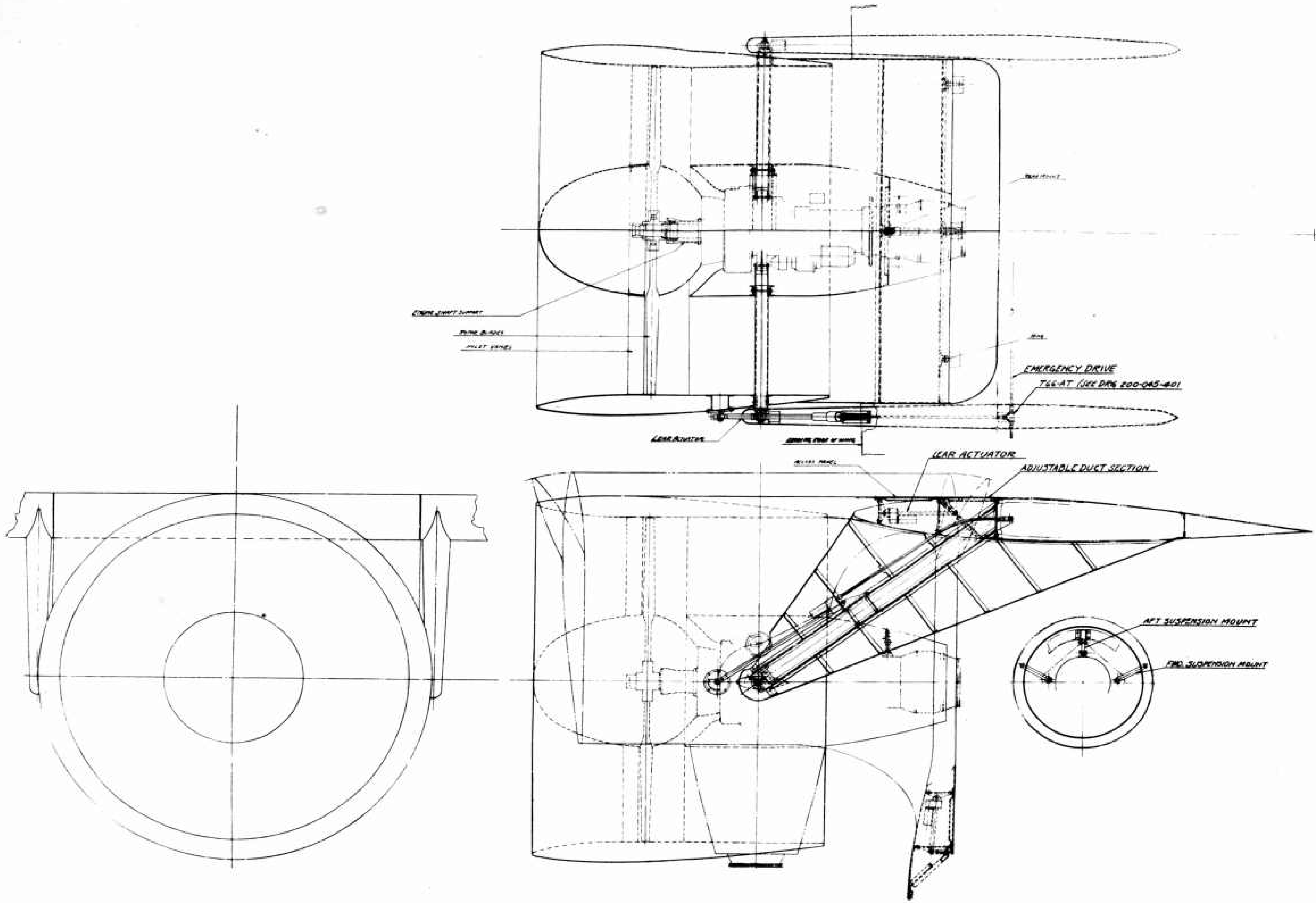

Figure 12. Dwg. No. D181-960-013: RB-109 Inboard Duct Arrangement

TABLE IV

FOUR-DUCT RB109 TILTING ENGINE CONFIGURATION

Ref. D181-960-007

	Weight
Wing	5200
Tail	
Horizontal	685
Vertical	486
Body	7423
Landing Gear	
Nose	400
Main	1900
Surface Controls	
Flight	500
Reaction Controls (Pitch)	400
Engine Section (Duct Around Prop)	
Inboard	3200
Outboard	5050
Propulsion	
Inboard Engines (2) RB109	3700
Outboard Engines (4) RB109	7400
Inboard Engine Gear Box (Incl. in Eng.)	--
Outboard Eng. Gear Boxes (2)	1544
Engine Mounts - Inboard	150
- Outboard	300
Duct Supports - Inboard	360
- Outboard	600
Rotating Mech.- Inboard	75
- Outboard	125
Lub. System	195
Fuel System	460
Water Injection System	200
Engine Controls	50
Starting System	150
Propeller Installation - Inboard	1200
- Outboard	2200
Auxiliary Power Plant	80
Instruments	160
Hydraulics (Brakes and Nose Steer.)	50
Electrical	800
Electronics	500
Furnishings (No Paratroop Seats)	465
Air Conditioning and Anti-Ice	500
Auxiliary Gear (Jacking, Towing)	25
Total Weight Empty	46533

		Weight
Useful Load		
Crew (3)		645
Oil-Engines		188
Gear Boxes		125
Fuel		13212
Water		1297
Payload		8000
	Total Useful Load	23467
Gross Weight (VTOL Position)		
Total Weight Empty		46533
Useful Load		23467
	Gross Weight	70000
Gross Weight Less Fuel		56788
Gross Weight Less Fuel and Payload		48788

V. ASSAULT TRANSPORT DESIGN STUDY

A. Four Duct Allison 550-B1 Configuration

As mentioned previously a configuration was designed using the Allison 550-B1 turboprop engine. From the outset it was thought that the use of this engine would result in a lighter, higher performance aircraft. The more powerful engines enabled the designer to reduce the duct size for the same gross weight. It is expected that the smaller duct diameter and higher propeller speed will result in lower propulsion system weight. The improved specific fuel consumption would tend to maintain aircraft endurance to roughly the same value for an unchanged fuel capacity while the maximum performance could be expected to increase.

A design study was undertaken to determine a practical configuration. It was decided that much of the configuration using the RB-109 engines could be used for this study. As a result, the initial step was to replace the ducted fan units with new ones containing the Allison 550 engines. The wing, fuselage, empennage, landing gear, etc. remained unchanged. The result of this study is shown in Figure 13. The possible reduction in duct size is obvious at a glance when compared to the RB-109 configuration. It is also evident from Figures 14 and 15 which show the Allison 550 installations in the outboard and inboard ducted fan units.

A comparison of the weight of this configuration with that of the RB-109 design is of interest. The gross weight of the aircraft has decreased

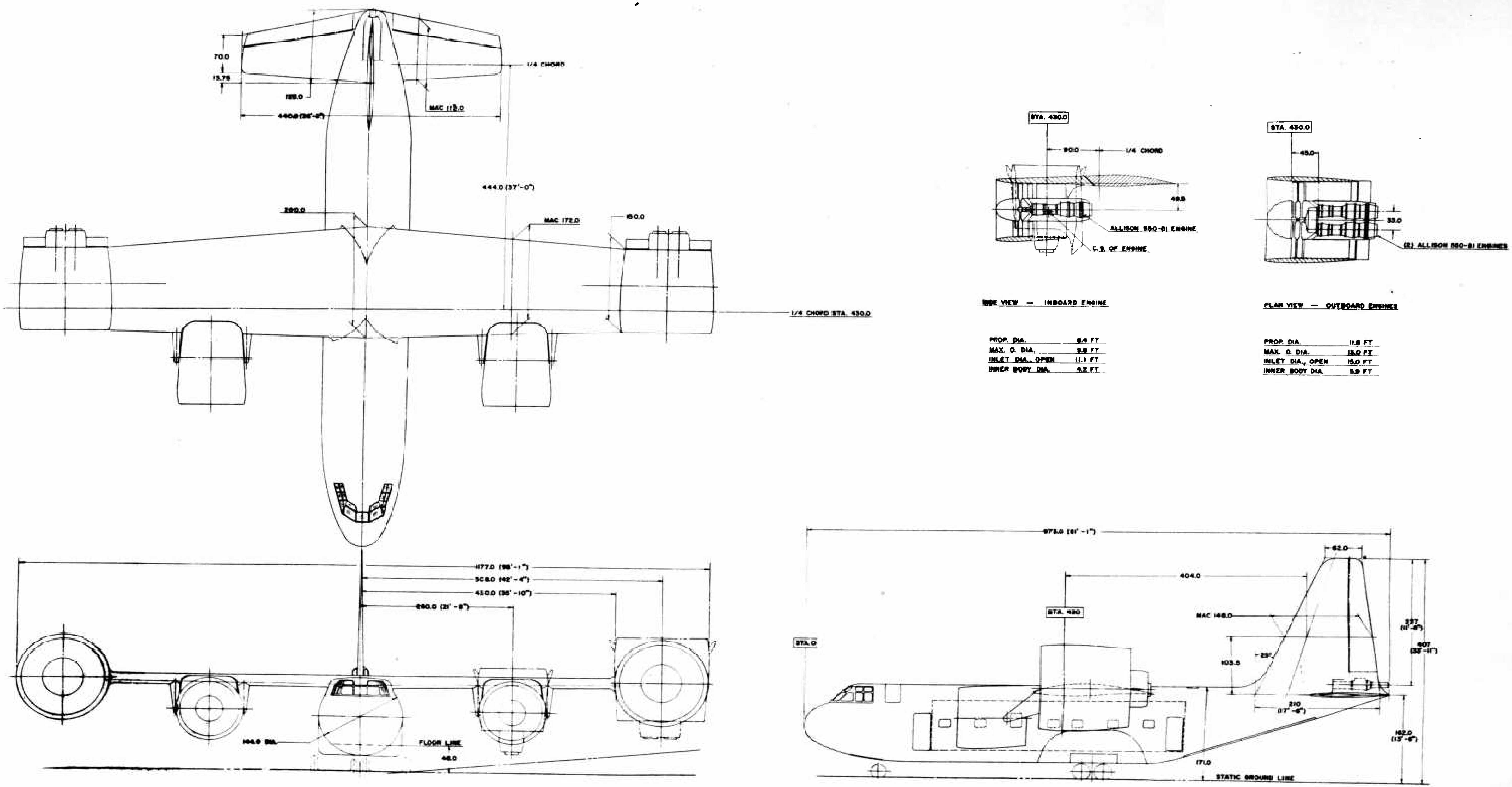

Figure 13. Dwg. No. D181-960-009: Four-Duct Allison 550-B1 Tilting Engine Configuration

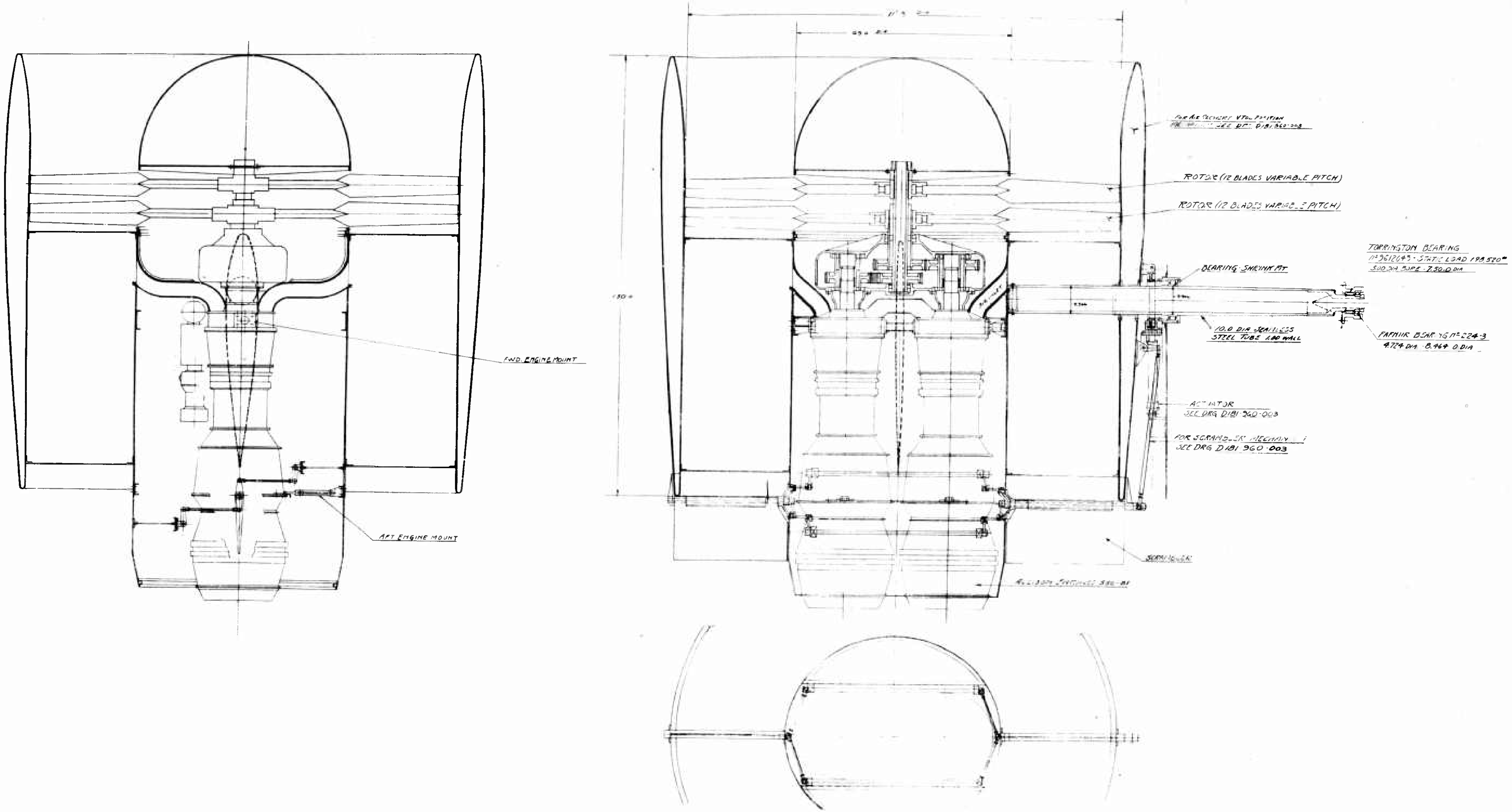

Figure 14. Dwg. No. D181-960-018: Allison 550 Outboard Duct Arrangement

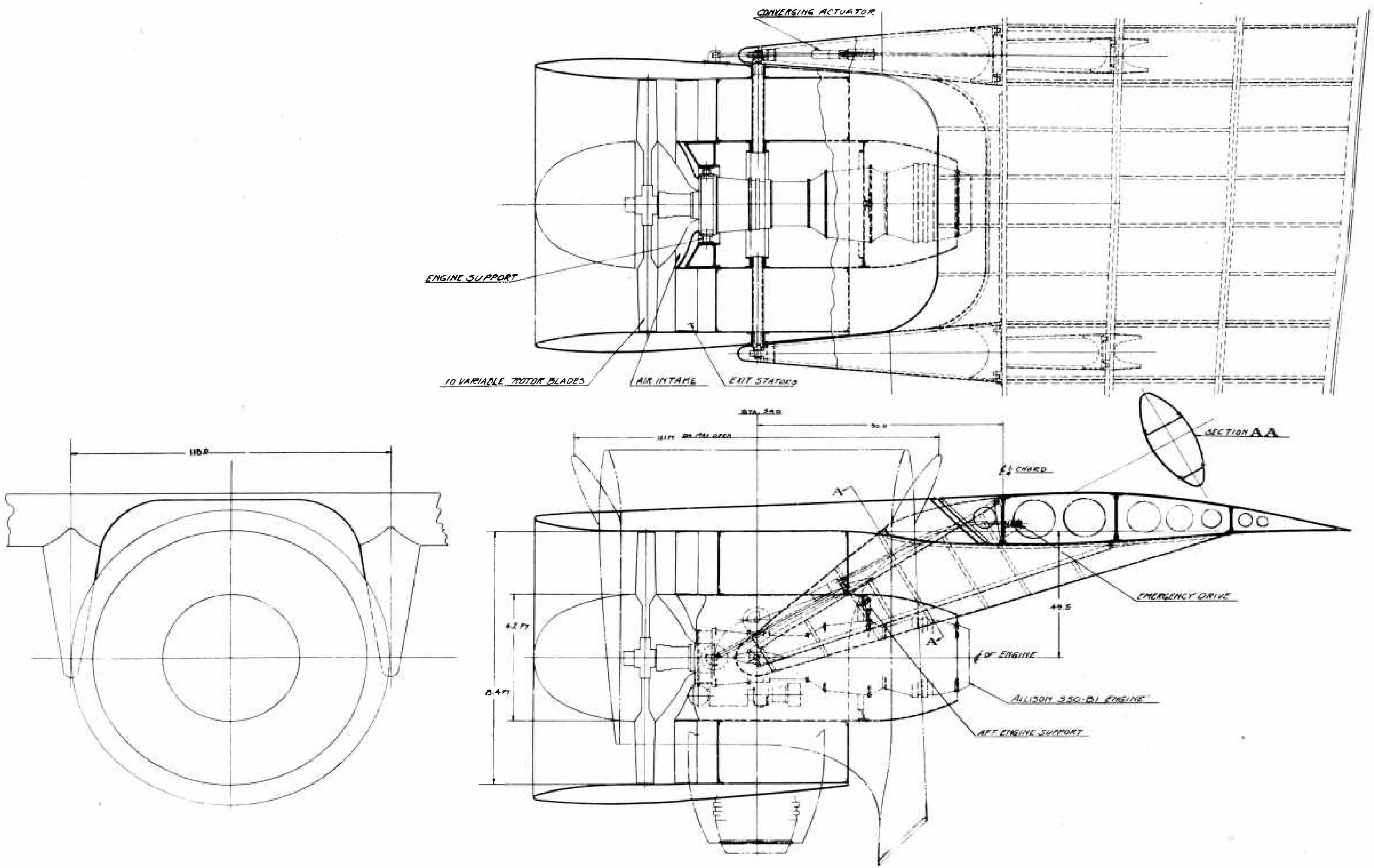

Figure 15. Dwg. No. D183-960-017: Allison 550 Inboard Duct Arrangement

to about 67,380 pounds, a difference of 2620 pounds. This could be utilized for increased payload or a larger fuel load for longer range performance.

The configuration which evolved during the course of the study employs four separate rotating ducted propeller units each with the power plants installed in the duct centerbody. The aircraft is characterized by a high wing, circular sectioned fuselage with integral rear loading ramp, and fuselage mounted landing gear. A three-man crew has been considered necessary to adequately perform the pilot and flight engineer functions for the aircraft.

In a VTOL aircraft the weight factor is all important, so that the utmost effort should be exerted to obtain light efficient structure taking advantage of advanced techniques and materials to achieve this end. Also, the equipment items should be selected carefully with due allowance for state of the art advances and restricting the systems to only those items which are necessary to perform the aircraft missions.

The Fairchild C-123 aircraft is the current operational Assault Transport and is in the same general weight class as the resulting Ducted Propeller Transport designs. The C-123 was conceived, designed and developed with the assault transport mission as its primary function. As a result, the same general approach was used in the determination of the design characteristics of the ducted propeller transports. Major emphasis has been placed upon design of a minimum gross weight airplane to perform the required mission. Only the equipment which is considered necessary to perform the basic mission is included. However, space provisions have been allocated for other items which will be needed for alternate missions and aircraft loadings.

B. Aircraft Systems and Component Descriptions

The inboard profile of the transport fuselage was the object of considerable design effort. The cockpit arrangement for the three-man crew was the subject of considerable design study. A circular cross-section was used for the pressurized body and the cargo and troop accommodation problems were studied in quite some detail. Troop seat and litter arrangements were varied to find optimum loading of the cargo compartment. Alternate cargo loadings were also considered. The large cargo loading ramp and door arrangement was studied.

In connection with the work on the inboard profile, research into the various items of fixed equipment was initiated. Data was collected and examined on instruments, crew furnishings, controls, air conditioning and pressurization equipment, electrical and communicating equipment, and survival gear. In addition, auxiliary power supply and cargo handling and tie-down equipment were considered briefly. The result of the inboard profile study is presented in Fig. 16. As stated previously, not all of the material described is installed in the basic aircraft but arrangements are made for installation when required.

Crew Compartment

The crew, consisting of the pilot, co-pilot and systems engineer is provided with a pressurized and environment controlled compartment. The control arrangement is standard, and the location of the instruments and windows are such as to provide excellent visibility for the pilot and co-pilot. The systems engineer, located aft of and between the pilots, is provided with an adjustable swivel seat to allow him easy access to the controls and instruments

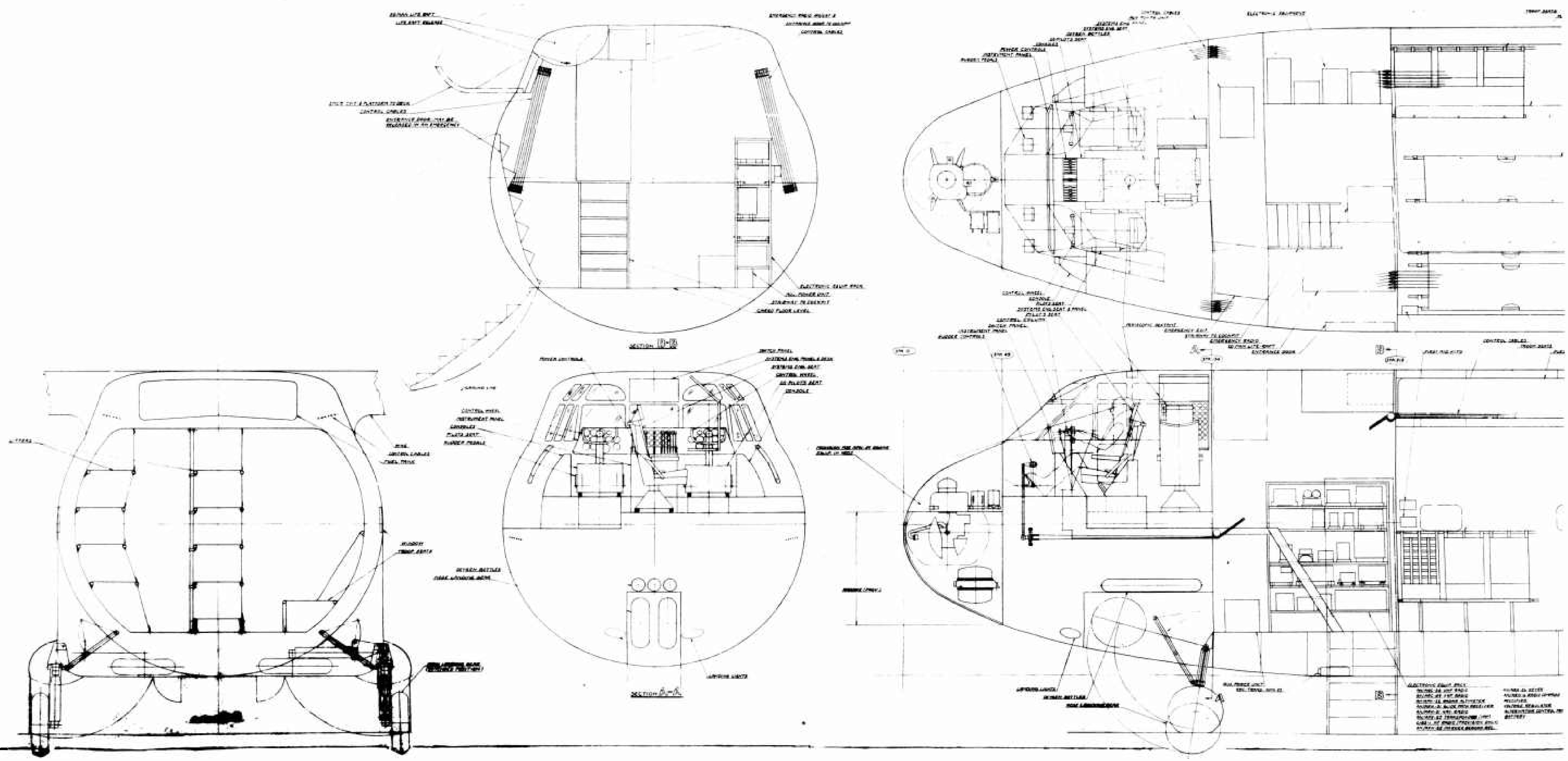

Figure 16. Dwg. No. D181-960-012: Assault Transport Inboard Profile (Sheet 1 of 2)

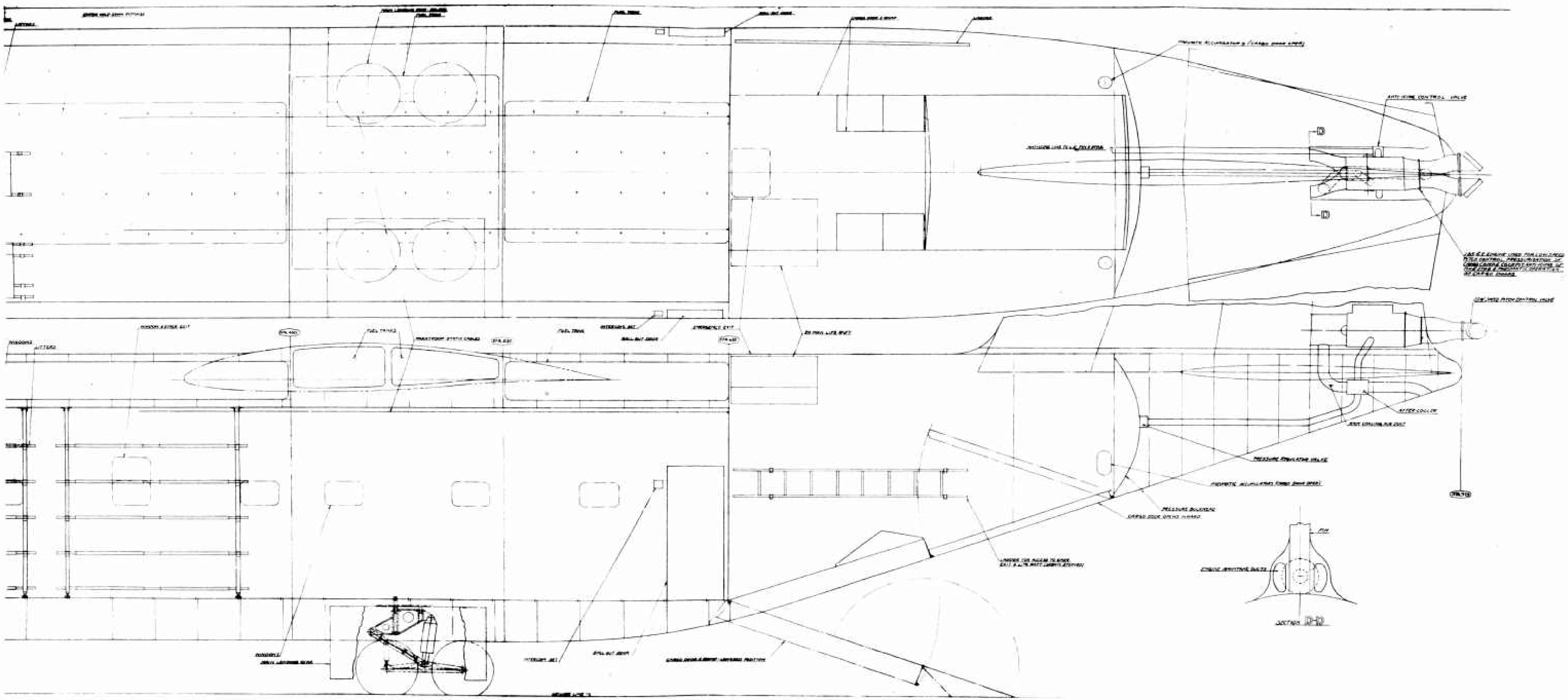

Figure 16. Dwg. No. D181-960-012: Assault Transport Inboard Profile (Sheet 2 of 2)

on the center console, as well as the switches and instruments on the panel located behind the co-pilot. Entrance to crew compartment is thru a large door on the L.H. side of airplane and up a stairway. An emergency exit is provided in the top of fuselage just aft of crew compartment or thru the entrance door which is jettisonable.

Environmental Control System

The crew compartment and the entire fuselage with the exception of the L.G. wheel wells back to the pressure bulkhead, aft of the cargo doors, is pressurized, heated and cooled. The source is a bleed from the J85 engine located in the aft end of the fuselage. This same source is utilized for anti-icing of the stabilizer and fin. A combustion heater is used for anti-icing the wing and supplements the engine supply for heating and defrosting the crew compartment. The necessary pressure regulators, heat exchangers, etc. to maintain the environment at a level for efficient operation are provided. A differential pressure to maintain a cabin altitude of 8000 feet to the normal flight altitude will be maintained.

Navigation System

The navigation system includes the following equipment:

AN/APN-22	Radar Altimeter
AN/ARN-31	Glide Path Receiver
AN/ARN-21	Radio
AN/APX-25	Transponder
AN/ARN-32	Marker Beacon Receiver
AN/ARN-6	Radio Compass

Provision is made in the nose of the fuselage for the installation of AN/APN-59 radar equipment. This set has search, weather mapping and terrain mapping capabilities.

The majority of the above equipment is located in racks in the compartment just aft of the crew compartment and is easily accessible for servicing and adjustment. The indicators are located on the instrument panel and the control boxes on the console between the pilots.

A periscopic sextant is provided in the crew compartment for celestial navigation.

Communication System

The communications system includes the following equipment:

AN/ARC-34 UHF Radio

AN/ARC-49 VHF Radio

Provision for the installation of 618S-1 HF Radio

AN/ARA-26 Keyer

AN/AIC-10 Intercommunication set with two stations in cargo compartment and one in crew compartment.

An emergency radio set CRT-3 is located in top of fuselage and is accessible thru the life raft door.

Cargo Compartment

Due to the fact that the fuselage is fully pressurized, a circular cross-section was maintained as nearly as possible. Therefore the width of the cargo compartment is greater at the center than at the floor level. The volume of the compartment is approximately 2600 ft^3, and is capable of taking a maximum varied cargo among which are the following:

59 Assault or paratroops

52 Litters

1 Field Ambulance 1-1/2 ton 4 x 2

2 Field Ambulances 3/4 ton 4 x 4

2 Cargo Carriers M29C (Amphibian)

1 Scout Car M3A1 4 x 4

2 Shovel Loaders, Tractor Mounted, Hydraulic, 1/3 cu. yd.

1 Tractor, High Speed 7 ton, M2

Various Small Trailers

3 Jeeps

2 1/2 ton Trucks 4 x 4 2 Trucks 3/4 ton 4 x 4 Weapons Carrier

Miscellaneous Small Arms and Equipment

Howitzers or Field Pieces

Large doors are located at the aft end of the compartment for rear loading. The floor level is 48" above the ground level (average truck bed level) and is capable of withstanding loads imposed by the above equipment. The doors are pneumatically operated (the air source being from the J85 engine to accumulators) and the ramp door can be raised to intermediate levels for convenient truck bed or platform loading as well as ground level ramp loading. Cargo, troop seat and litter hold-down fittings are provided in the floor and are located according to HIAD AD7. Fuselage frames and longitudinal beams are so placed that each fitting is located at the intersection and is properly reinforced under the floor. Troops may enter thru the cargo ramp door. This ramp may be used for bail-out of paratroops or dropping of cargo. Doors are also provided on each side of the fuselage adjacent to cargo doors for evacuation of troops. In case of ditching emergency exits are provided in the top of fuselage, also in the sides just forward of the wing.

Survival Equipment

Two automatically inflated 20-man life rafts are provided. These are in built-in containers in the top of fuselage. The forward one is located aft of the crew compartment, access to which is thru an emergency door and platform located on L.H. side. The rear one is located aft of the cargo compartment, and adjacent to an emergency exit. A ladder is provided to this exit. Additional manually operated life rafts will be lashed near appropriate exits when carrying a full complement of troops. An emergency radio is located adjacent to the forward life raft and is accessible thru the raft compartment when the raft is released.

First Aid kits are located in the crew compartment and also in the cargo compartment.

Oxygen System

A low pressure oxygen system is provided for the crew only, in the event of pressurization failure. Masks, demand regulators and pressure gages are located at each crew station. A filler valve is located in the nose wheel well.

Hydraulic System

A 3000 psi hydraulic system is provided as the power source for nose wheel steering and parking brakes. Engine driven hydraulic pumps are installed on each of the two inboard engines.

Electrical System

The primary electrical power source is from two alternators mounted on the accessory pads of the inboard engines. This AC system is fully automatic in operation and incorporates a maximum of automatic circuit protection features. Direct current of 28 volts is obtained by rectification of the primary A.C. current.

Emergency power, in the event of failure of the primary source, is provided by a gas turbine auxiliary power unit furnishing A.C. power.

The components requiring A.C. power are as follows:

Transponder Set AN/APX-25

Radio Compass AN/ARN-6

Glide Path Receiver AN/ARN-31

Radar Altimeter AN/APN-22

H.F. Radio 618 S-1 (provision only)

Radar Set AN/APN-59 (provision only)

Nose and Main Landing Gear Actuators

Fuel Pumps

Rectifier

Aircraft Lighting

The components requiring DC power are as follows:

Marker Beacon Receiver	AN/ARN-32
Transponder Set	AN/APX-25
Radio Compass	AN/ARN-6
Glide Path Receiver	AN/ARN-31
Radar Altimeter	AN/APN-22
Keyer	AN/ARA-26

VHF Radio AN/ARC-49

UHF Radio AN/ARC-34

Engine Duct Rotation Actuators

Control Surface Trim Actuators

Intercommunication Set AN/AIC-10

HF Radio 618S-1 (provision only)

Radar Set AN/APN-59 (provision only)

AC and DC external power receptacles are provided for ground operation and testing.

Aerodynamic Surface Controls

The aerodynamic surfaces are actuated by dual cable systems. Balance of the elevator and rudder surfaces, and sealing between the fixed and moveable surfaces, reduces the hinge moments and allows the use of a mechanical control system without the aid of power assists. Cables are routed so as to keep the bends at a minimum, thereby reducing friction.

Trim tabs are provided on the rudder and elevators and the electric actuators are controlled by switches located in the crew compartment.

Longitudinal control during hovering or low speeds is provided by the jet thrust from the J85 engine located in the aft end of the fuselage. Lateral and directional control is provided by controllable surfaces located in the aft portion of the outboard ducts.

Landing Gear

A tricycle type landing gear is provided. The nose gear has dual wheels and is conventional in design. Retraction of gear is forward into fuselage and is accomplished electrically. Hydraulic nose wheel steering and parking brakes are included. The main gear has two tandem wheels located on each side of the fuselage. Retraction of this gear is inboard into the fuselage and is accomplished electrically. Position indicator and controls and warning lights are located in the crew compartment.

Power Plant and Controls

Six Allison 550-B1 engines are installed in ducted nacelles in the wing. Each inboard nacelle contains a single engine and propeller, while the outboard nacelles contain two engines each which drive separate contra-rotating propellers. An automatic torque sensing device is incorporated for equalizing opposing engines, i.e., if one engine loses power or fails, the engine on the opposite side is cut back or shut off. The power controls and engine switches are located on the console between the pilots. Engine instruments are installed on flight engineer's panel.

For VTOL or STOL operation the nacelles (ducts) are rotated by electric actuators. Switches on the control wheel of the pilot and co-pilot initiate the rotation and indicators on the instrument panel show the extent of rotation. For VTOL the nacelles are rotated 90° and for STO (short take-off), approximately 45° aft. When decelerating for vertical landing the nacelles are rotated 10° forward of vertical. The actuator motors are powered by the primary electrical system. However, a separate emergency motor, powered by the auxiliary power system, is provided in the event of failure of the primary system. This emergency motor drives a coordinating shaft which rotates all nacelles.

Fuel System

The fuel system consists of 6 fuel tanks pressurized to 5 psi by engine bleed air. Two tanks are located in the fuselage, one forward and one aft of the wing. The other four tanks are located in the wing center section. The total capacity is 13295 pounds (2045 gal.). An additional 12700 pounds of fuel may be carried in the wing. Fuel is programmed to keep c.g. movement to a minimum and the tanks are so interconnected as to make fuel available to any engine without interruption of flow.

This system feeds the G.E. J-85 engine located in the aft end of the fuselage as well as the six Allison 550-B1 engines in the wing nacelles.

C. Structures and Weights

General

The structural configuration of the D181 assault transport is generally conventional in that aluminum alloy, stringer stiffened shell structure is used for the pressurized fuselage and the lifting surfaces. The fuselage structure contains a number of door and window cutouts, typical of a transport; in particular there is a large cargo loading door in the rear lower surface of the fuselage. All cutouts are longeron reinforced. Unconventional aspects of the structure arise from the ducted fans. Each fan, complete with engine, is carried in a nacelle structure, supported in turn by radial spokes within the ducts. The complete duct assemblies, one at each wing tip and one at the 60% of span station of each wing panel, are hinged about the pitch axis.

In view of the conventional structure, the minimum of stress analysis has been performed, to justify feasibility and the weight estimate. This section therefore contains only a structural description and, where necessary a brief discussion of the reasons for the structural arrangements. Basic structural criteria and loads are presented in the Preliminary Structural Analysis (Ref. 5).

Lifting Surfaces.

The lifting surfaces (wing, horizontal and vertical tails) are stringer stiffened covers of 7075-T6 aluminum alloy material with three spanwise shear webs. This type construction is the optimum structure for the low intensity cover loading present in this configuration, and is shown in the wing and tail structural assembly drawing, Figs. 17 and 18.

The wing is made up of two panels of which the structural section between the front and rear spars, carries through the fuselage. These two panels are spliced together at the airplane centerline by means of match angle fittings. Ribs are provided at the splice to distribute the loads. The wing-fuselage attachment is accomplished by bolted connections at four points. Fittings are provided to distribute the loads to the front and rear spars and a root rib. Fittings and ribs are also provided at the inboard and outboard duct support points to distribute the loads from these ducts into the wing structure. Because of the large masses of the ducts located outboard on the wing, the wing has been designed for compression in both the upper and lower surfaces. Critical conditions are vertical take-off (compression in the upper surface) and taxiing (compression in the lower surface). Ribs have been spaced at 20 inch centers, along the wing span to stabilize the stringers.

The vertical tail is attached to the fuselage by six bolts through fittings which attach to the three spars and a closure rib. The load is

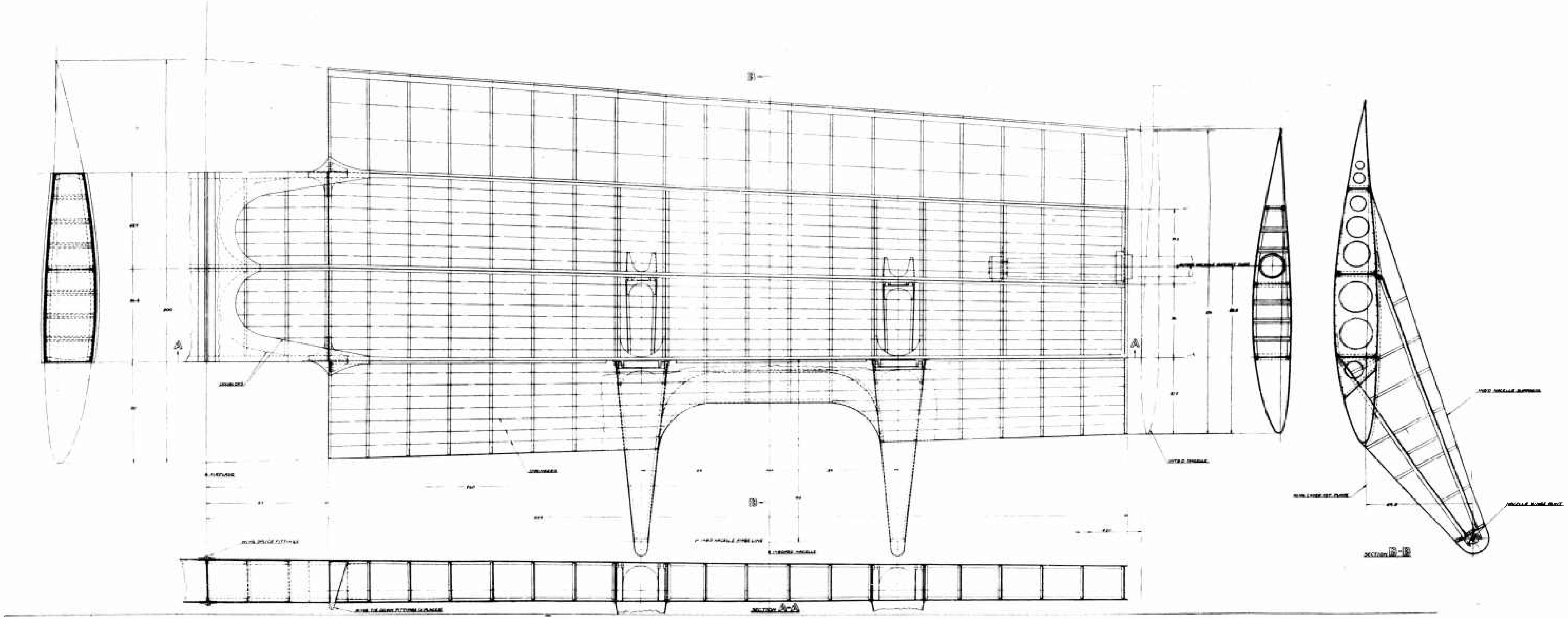

Figure 17. Dwg. No. D181-960-019, Sheet 2: Wing Structural Assembly

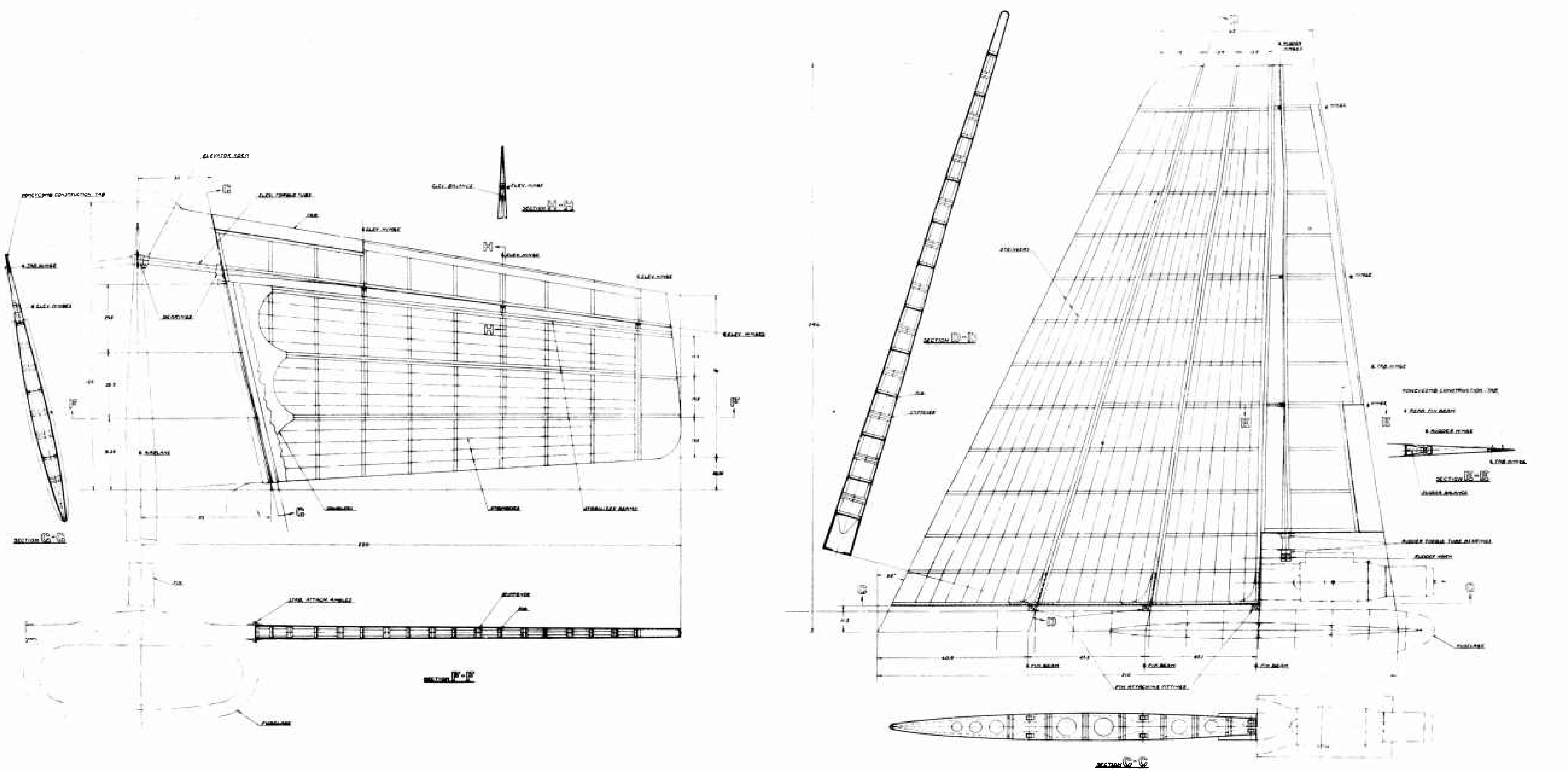

Figure 18. Dwg. No. D181-960-019; Sheet 2: Tail Surface Structural Assemblies

distributed to the fuselage by fittings which are fastened to three fuselage frames. The horizontal tail is fabricated as two outer panels which are fastened directly to the fuselage by match angle fittings. The mating fuselage frames provide the stabilizer carry-through structure across the fuselage and supply the bending rigidity required. This is accomplished by providing a web with upper and lower caps across each frame. Large doublers at the stabilizer root collect the stringer loads and concentrate them at the spar caps. Ribs have been spaced along the span of both the fin and stabilizer to stabilize the stringers and also to distribute the concentrated hinge loads from the rudder and elevator.

Fuselage.

The fuselage, Fig. 19, is constructed primarily of stringer stiffened skin in 2024-T3 aluminum alloy, stabilized by frames. This construction is again dictated by the low axial loading in the skin, which results from the large depth and breadth of the fuselage. Since the fuselage is pressurized, but is not completely circular at all stations, the stringers are also necessary to carry pressure loads not resisted by skin tension.

The fuselage contains a number of doors and windows, a cutout for the wing, and a large cargo loading door in the lower surface at the rear. Reinforcements around these cutouts are sufficiently extensive that four continuous longerons result. Heavy frames are provided to distribute wing, tail surface and landing gear loads.

The cabin area is designed to maintain 8000 feet pressure altitude at 30,000 feet actual altitude and a domed bulkhead is provided at the rear to terminate the pressurized area. Where the cargo loading door removes a

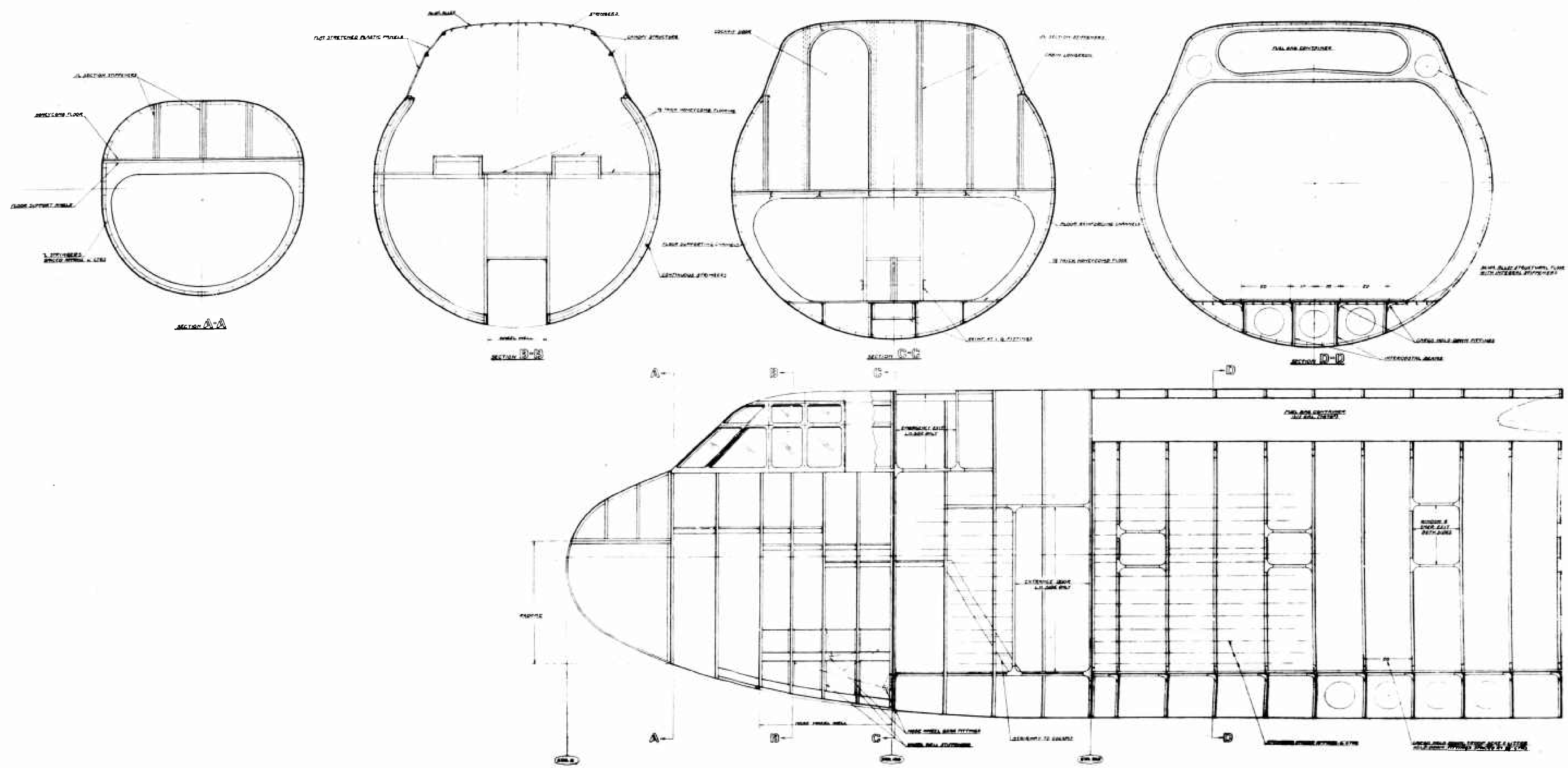

Figure 19. Dwg. No. D181-960-019, Sheet 1: Fuselage Structural Assembly (Sheet 1 of 2)

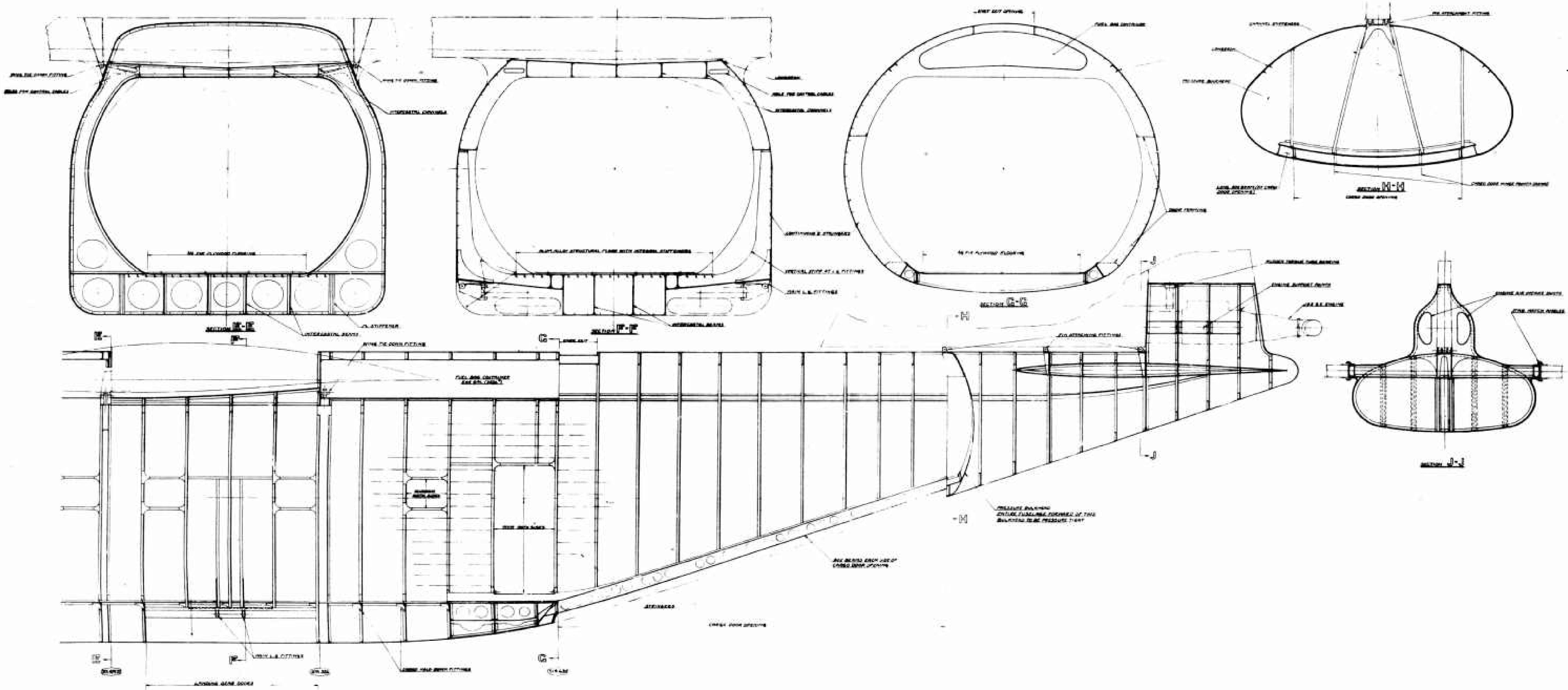

Figure 19. Dwg. No. D181-960-019, Sheet 1: Fuselage Structural Assembly (Sheet 2 of 2)

large area of the lower fuselage shell, provision is made in the door fastenings to carry the "bursting" loads due to pressure.

The lower part of each frame in the cargo compartment area forms a deep cross-beam supporting the cargo floor; which is aluminum sheet stiffened by longitudinal angle section stringers. Fuel is carried in a flat lined cell between the ceiling and the top outer skin. Again the cargo compartment ceiling is stringer stiffened to carry the fuel weight, while the area around the cell is vented to cabin pressure, so that pressure loads are carried by the outside fuselage shell.

Landing Gear

For landing, a tricycle type gear mounted in the fuselage has been provided. The nose gear has a dual wheel and is conventional in design. The main gear consists of two tandem wheeled gears mounted at each side of the fuselage. Each gear is mounted to a single fitting which is hinged to the fuselage, thereby making it possible to fold the gear into the fuselage. Because of this, the side load on the gear, which imposes torque on this fitting, is the critical design condition.

Weight Estimation.

The estimated weight and balance calculations are consistent with the preliminary structural weight data employed in the analysis. Conventional methods of weight estimate were used in determining the structural weights. A group weight statement for the Allison 550-B1 tilting engine configuration is presented in Table V.

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TABLE V

GROUP WEIGHT STATEMENT

ESTIMATED - CALCULATED - ACTUAL

(Cross out those not applicable)

CONTRACT NO. Nonr-1675(00)
AIRPLANE, GOVERNMENT NO.
AIRPLANE, CONTRACTOR NO. D181-960-009
MANUFACTURED BY Bell Aircraft Corporation

		MAIN	AUXILIARY
ENGINE	MANUFACTURED BY	Allison	
	MODEL	550-B1 (6)	
	NO.		
PROPELLER	MANUFACTURED BY		
	DESIGN NO.		
	NO.		

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AN-9103-D
NAME
DATE

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

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MODEL D181
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1	WING GROUP		5200
2	CENTER SECTION - BASIC STRUCTURE		
3	INTERMEDIATE PANEL - BASIC STRUCTURE		
4	OUTER PANEL - BASIC STRUCTURE (INCL. TIPS LBS.)		
5			
6	SECONDARY STRUCTURE (INCL. WINGFOLD MECHANISM LBS.)		
7	AILERONS (INCL. BALANCE WEIGHT LBS.)		
8	FLAPS - TRAILING EDGE		
9	- LEADING EDGE		
10	SLATS		
11	SPOILERS		
12	SPEED BRAKES		
13			
14			
15	TAIL GROUP		1171
16	~~STABILIZER - BASIC STRUCTURE~~ Horizontal	685	
17	FINS - BASIC STRUCTURE (INCL. DORSAL LBS.)		
18	SECONDARY STRUCTURE (STAB. & FINS)		
19	~~ELEVATOR (INCL. BALANCE WEIGHT~~ LBS.) Vertical	486	
20	RUDDERS (INCL. BALANCE WEIGHT LBS.)		
21			
22			
23	BODY GROUP		7423
24	FUSELAGE OR HULL - BASIC STRUCTURE		
25	BOOMS - BASIC STRUCTURE		
26	SECONDARY STRUCTURE - FUSELAGE OR HULL		
27	- BOOMS		
28	- SPEEDBRAKES		
29	- DOORS, PANELS & MISC.		
30			
31	ALIGHTING GEAR GROUP - LAND (TYPE:)		2230

	LOCATION	WHEELS, BRAKES TIRES, TUBES, AIR	STRUCTURE	CONTROLS		
32–33						
34	Nose				300	
35	Main				1930	
36						
37						
38						
39						

40	ALIGHTING GEAR GROUP - WATER					
41	LOCATION	FLOATS	STRUTS	CONTROLS		
42						
43						
44						
45						

46	SURFACE CONTROLS GROUP		900
47	COCKPIT CONTROLS		
48	AUTOMATIC PILOT	500	
49	SYSTEM CONTROLS (INCL. POWER & FEEL CONTROLS LBS.)		
50	Reaction Controls	400	
51	ENGINE SECTION OR NACELLE GROUP		7870
52	INBOARD Ducts, Mounts and Supports	3205	
53	CENTER		
54	OUTBOARD Ducts, Mounts and Supports	4665	
55	~~DOORS, PANELS & MISC.~~		
56			
57	TOTAL (TO BE BROUGHT FORWARD)		24794

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GROUP WEIGHT STATEMENT
WEIGHT EMPTY

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		AUXILIARY	MAIN	
1	PROPULSION GROUP			16441
2		AUXILIARY	MAIN	
3	ENGINE INSTALLATION 550-B1 (6)		9450	
4	AFTERBURNERS (IF FURN. SEPARATELY)			
5	ACCESSORY GEAR BOXES & DRIVES (4)		3160	
6	~~SUPERCHARGERS (FOR TURBO TYPES)~~			
7	~~AIR INDUCTION SYSTEM~~			
8	~~EXHAUST SYSTEM~~ Rotating Mech.		160	
9	COOLING SYSTEM			
10	LUBRICATING SYSTEM		195	
11	TANKS			
12	COOLING INSTALLATION			
13	DUCTS, PLUMBING, ETC.			
14	FUEL SYSTEM		460	
15	TANKS - PROTECTED			
16	UNPROTECTED			
17	PLUMBING, ETC			
18	WATER INJECTION SYSTEM		200	
19	ENGINE CONTROLS		50	
20	STARTING SYSTEM		150	
21	PROPELLER INSTALLATION			
22	Inboard		1094	
23	Outboard		1522	
24	AUXILIARY POWER PLANT GROUP			80
25	INSTRUMENTS & NAVIGATIONAL EQUIPMENT GROUP			160
26	HYDRAULIC & PNEUMATIC GROUP			50
27				
28				
29	ELECTRICAL GROUP			800
30				
31				
32	ELECTRONICS GROUP			500
33	EQUIPMENT			
34	INSTALLATION			
35				
36	ARMAMENT GROUP (INCL. GUNFIRE PROTECTION LBS.)			
37	FURNISHINGS & EQUIPMENT GROUP			465
38	ACCOMMODATIONS FOR PERSONNEL			
39	MISCELLANEOUS EQUIPMENT			
40	FURNISHINGS			
41	EMERGENCY EQUIPMENT			
42				
43	AIR CONDITIONING & ANTI-ICING EQUIPMENT GROUP			500
44	AIR CONDITIONING			
45	ANTI-ICING			
46				
47	PHOTOGRAPHIC GROUP			25
48	AUXILIARY GEAR GROUP			
49	HANDLING GEAR			
50	ARRESTING GEAR			
51	CATAPULTING GEAR			
52	ATO GEAR			
53				
54				
55	MANUFACTURING VARIATION			
56	TOTAL FROM PG. 2			24794
57	WEIGHT EMPTY			43815

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GROUP WEIGHT STATEMENT
USEFUL LOAD & GROSS WEIGHT

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1	LOAD CONDITION							
2								
3	CREW (NO.)				645			
4	PASSENGERS (NO.)							
5	FUEL	Type	Gals.					
6	UNUSABLE							
7	INTERNAL	JP-4	2064		13295			
8								
9								
10	EXTERNAL							
11								
12	BOMB BAY							
13								
14	OIL							
15	TRAPPED							
16	ENGINE				188			
17	Gear Boxes				140			
18	FUEL TANKS (LOCATION)							
19	WATER INJECTION FLUID (GALS)				1297			
20								
21	BAGGAGE							
22	CARGO				8000			
23								
24	ARMAMENT							
25	GUNS (Location)	Fix. or Flex.	Qty.	Cal.				
26								
27								
28								
29								
30								
31								
32	AMMUNITION							
33								
34								
35								
36								
37								
38								
39	INSTALLATIONS (BOMB, TORPEDO, ROCKET, ETC.)							
*40	BOMB OR TORPEDO RACKS							
41								
42								
43								
44								
45								
46	EQUIPMENT							
47	PYROTECHNICS							
48	PHOTOGRAPHIC							
49								
*50	OXYGEN							
51								
52	MISCELLANEOUS							
53								
54								
55	USEFUL LOAD				23565			
56	WEIGHT EMPTY				43815			
57	GROSS WEIGHT				67380			

*If not specified as weight empty.

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GROUP WEIGHT STATEMENT
DIMENSIONAL & STRUCTURAL DATA

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1	LENGTH - OVERALL (FT.)	81 ft. - 1 in.		HEIGHT - OVERALL - STATIC (FT.)				
2		Main Floats	Aux. Floats	Booms	Fuse or Hull	Nacelles Inboard	Nacelles Center	Nacelles Outboard
3	LENGTH - MAX. (FT.)				81.1			
4	DEPTH - MAX. (FT.)				12			
5	WIDTH - MAX. (FT.)				12			
6	WETTED AREA (SQ. FT.)				2600	800		1264
*7	FLOAT OR HULL DISPL. - MAX (LBS.)							

8	FUSELAGE VOLUME (CU. FT.)	PRESSURIZED	TOTAL		
9			Wing	H. Tail	V. Tail
10	GROSS AREA (SQ. FT.)		1045	298	212
11	WEIGHT/GROSS AREA (LBS./SQ. FT.)		5.0	2.3	2.3
12	SPAN (FT.)		71.7	36.6	11.4
13	FOLDED SPAN (FT.)				
14					
15	SWEEPBACK - AT 25% CHORD LINE (DEGREES)				
16	- AT % CHORD LINE (DEGREES)		0	5	25
**17	THEORETICAL ROOT CHORD - LENGTH (INCHES)		200	125	210
18	- MAX. THICKNESS (INCHES)		24	10	17
***19	CHORD AT PLANFORM BREAK - LENGTH (INCHES)				
20	- MAX. THICKNESS (INCHES)				
**21	THEORETICAL TIP CHORD - LENGTH (INCHES)		150	70	62
22	- MAX. THICKNESS (INCHES)		18	5.6	5
23	DORSAL AREA, INCLUDED IN (FUSE.) (HULL) (V. TAIL) AREA (SQ. FT.)				
24	TAIL LENGTH - 25% MAC WING TO 25% MAC H. TAIL (FT.)				

25	AREAS (SQ. FT.)	Flaps	L.E.	T.E.	
26		Lateral Controls	Slats	Spoilers	Ailerons
27		Speed Brakes	Wing	Fuse. or Hull	
28					
29					

30	ALIGHTING GEAR (LOCATION)				
31	LENGTH - OLEO EXTENDED - ℄ AXLE TO ℄ TRUNNION (INCHES)				
32	OLEO TRAVEL - FULL EXTENDED TO FULL COLLAPSED (INCHES)				
33	FLOAT OR SKI STRUT LENGTH (INCHES)				
34	ARRESTING HOOK LENGTH - ℄ HOOK TRUNNION TO ℄ HOOK POINT (INCHES)				
35	HYDRAULIC SYSTEM CAPACITY (GALS.)				

36	FUEL & LUBE SYSTEMS	Location	No. Tanks	****Gals. Protected	No. Tanks	****Gals. Unprotected
37	Fuel - Internal	Wing				
38		Fuse. or Hull				2064
39	- External					
40	- Bomb Bay					
41						
42	Oil					
43						
44						

45	STRUCTURAL DATA - CONDITION	Fuel in Wings (Lbs.)	Stress Gross Weight	Ult. L.F.
46	FLIGHT		68000	4.5
47	LANDING			
48				
49	MAX. GROSS WEIGHT WITH ZERO WING FUEL			
50	CATAPULTING			
51	MIN. FLYING WEIGHT			
52	LIMIT AIRPLANE LANDING SINKING SPEED (FT./SEC.)			
53	WING LIFT ASSUMED FOR LANDING DESIGN CONDITION (%W)			
54	STALL SPEED - LANDING CONFIGURATION - POWER OFF (KNOTS)			
55	PRESSURIZED CABIN - ULT. DESIGN PRESSURE DIFFERENTIAL - FLIGHT (P.S.I.)			
56				
57	AIRFRAME WEIGHT (AS DEFINED IN AN-W-11) (LBS.)			

*Lbs. of sea water (64 lbs./cu. ft.
**Parallel to ℄ of airplane.

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***Parallel to ℄ airplane.
****Total usable capacity.

VI. AIRCRAFT SAFETY

A. General.

The problem of safety is encountered in aircraft of every type. An additional factor which must be considered by the designer of VTOL aircraft is the loss of power in the hovering phases of the flight plan. The study requirement for the aircraft stipulates that the aircraft should be capable of a controlled crash landing in case of emergencies arising during hovering flight.

It is generally accepted that the VTOL aircraft type under consideration will not be designed with hovering as its principal mission. The conception has been that the aircraft will pass through the vertical and transition flight phases as quickly as practicable during landing and take-off operations. Missions requiring any lengthy hovering time are considered secondary to the primary use as assault transports.

The safety and survival of the aircraft crew and passengers is the principle objective of any investigation of the problem. Therefore, the study was undertaken to provide some insight into the major design parameters which must be considered in the successful solution of the safety problem. The investigation may be subdivided into several definite phases, each amenable to study as a problem in itself. The attempt here has been to delineate these lines of study and to determine the quantitative range of values for the factors involved. The investigation is roughly organized into three areas: 1. Aircraft Behavior, 2. Physiological Effects, and 3. Design.

B. Aircraft Behavior

Acceleration.

The complete or partial failure of the vertical thrust producing units on the hovering aircraft will result in a net accelerating force in the downward direction. The magnitude of the accelerating force is directly proportional to the extent of power failure. In the multiple engine aircraft which are presently under consideration, the possibility of total failure or 100% thrust loss is extremely remote. Consider the case of a six engine configuration which is presented in Fig. 20. Curves of impact velocity variation with height of fall are shown for the case of four, two or zero engines operating. The maximum hovering altitude has been shown at 50 feet, the obstacle height requirement for performance of these aircraft. With four engines operating, the impact velocity from 50 feet is about 21 MPH and time of descent is about three seconds. At the extreme case of full power failure, the impact velocity is 38 MPH in about 1.8 seconds time. These values have been computed with the assumption of instantaneous power loss which is not representative of the probable actual conditions. The inertia energy of the rotating components would result in a gradually reducing thrust level.

Deceleration.

The impact of the descending aircraft with the ground will result in the deceleration of the aircraft and i's contents. The exact nature of the deceleration process is very complex and not easily amenable of solution. However, a very general type of study can be made to determine the magnitude of the average loading which must be applied to the aircraft in order to come

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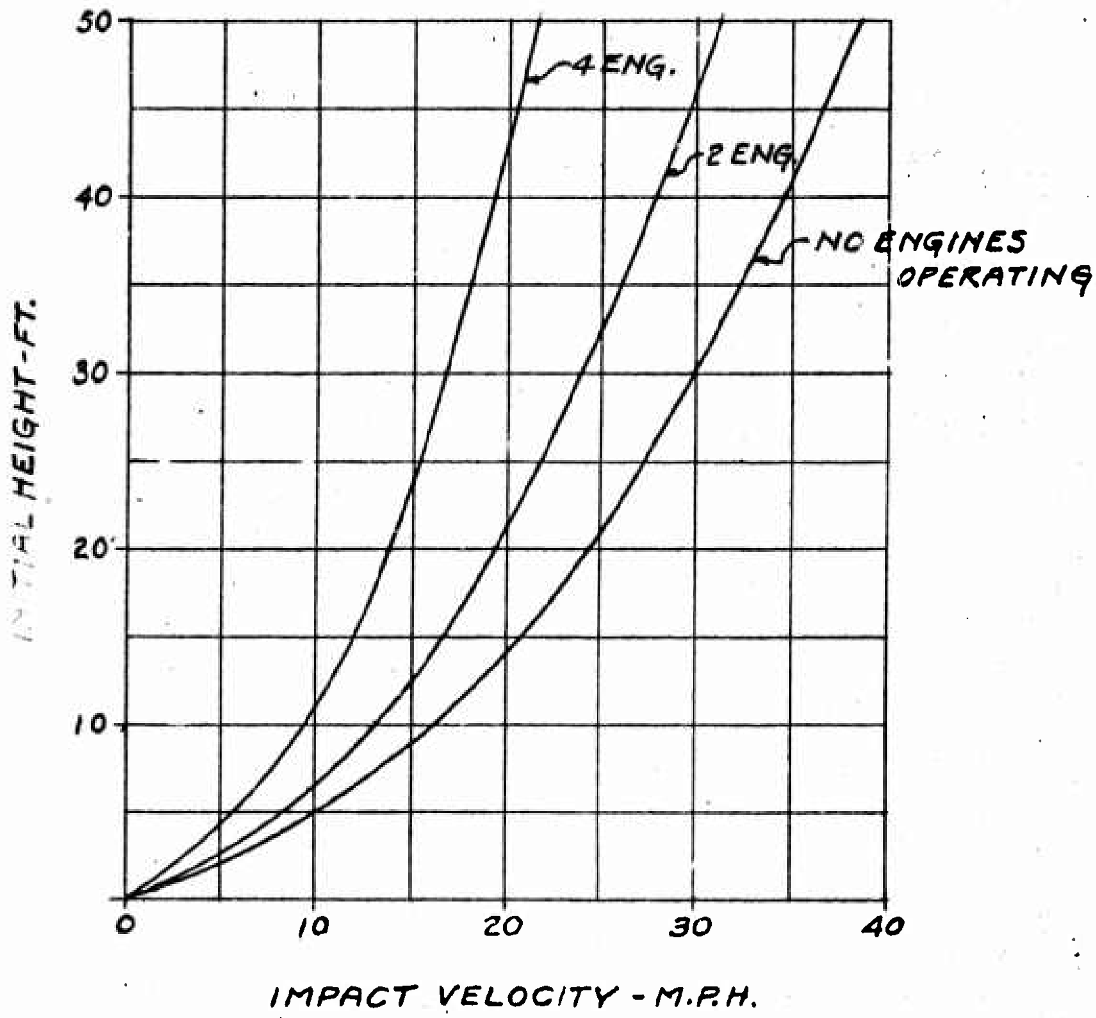
FIGURE 20
IMPACT VELOCITY FOR VARIOUS
DEGREES OF POWER FAILURE

ENGINE FAILURE DURING HOVERING



to a complete stop. The result of this study is presented in Fig. 21. Here the variation of deceleration distances required is shown versus impact velocity. A family of such curves is presented to show the effect of different constant deceleration g loadings. The time required for deceleration at the different loadings can also be read from the plot. For instance, a 15 g deceleration with an initial impact velocity of 25 mph would be accomplished in about three feet of distance and require about .08 seconds of time.

C. Physiological Effects.

As the aircraft decelerates, the crew and passengers will also be subject to deceleration. In each case the rate of deceleration on-set and the peak and average forces which act upon them cannot be determined without exhaustive investigation and analysis. However, the general information on the limits of human tolerance to the type of g loading which can be expected during an emergency landing of the VTOL airplane can be presented (Fig. 22). Examination of this data (Ref. 6) shows that even under the extremely pessimistic assumptions of acceleration and deceleration presented in the preceding figures, the human resistance to the decelerations imposed for the periods of time required are still within the limits of human tolerance. The example examined previously in which a 15g deceleration is imposed for .08 seconds can be seen to be well within the tolerance boundary. This assumes that the person is rigidly attached to the structure and is subject to the full deceleration experience by it. In actual conditions, this is seldom the case.

D. Design for Safety

Aside from the universal concept of ultimate system reliability, there are many other features which can be incorporated in the design of an opera-

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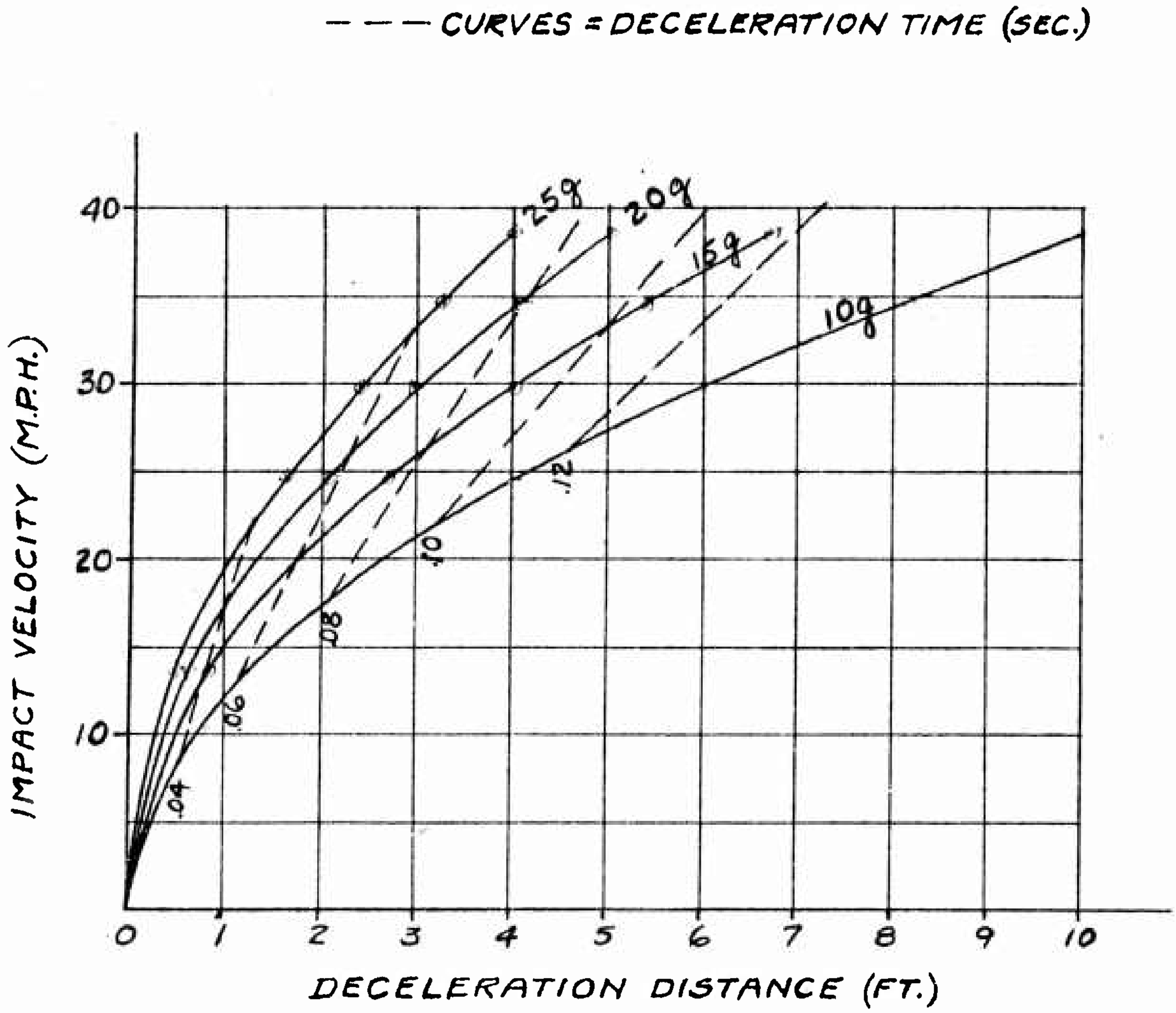
FIGURE 21

DECELERATION CHARACTERISTICS



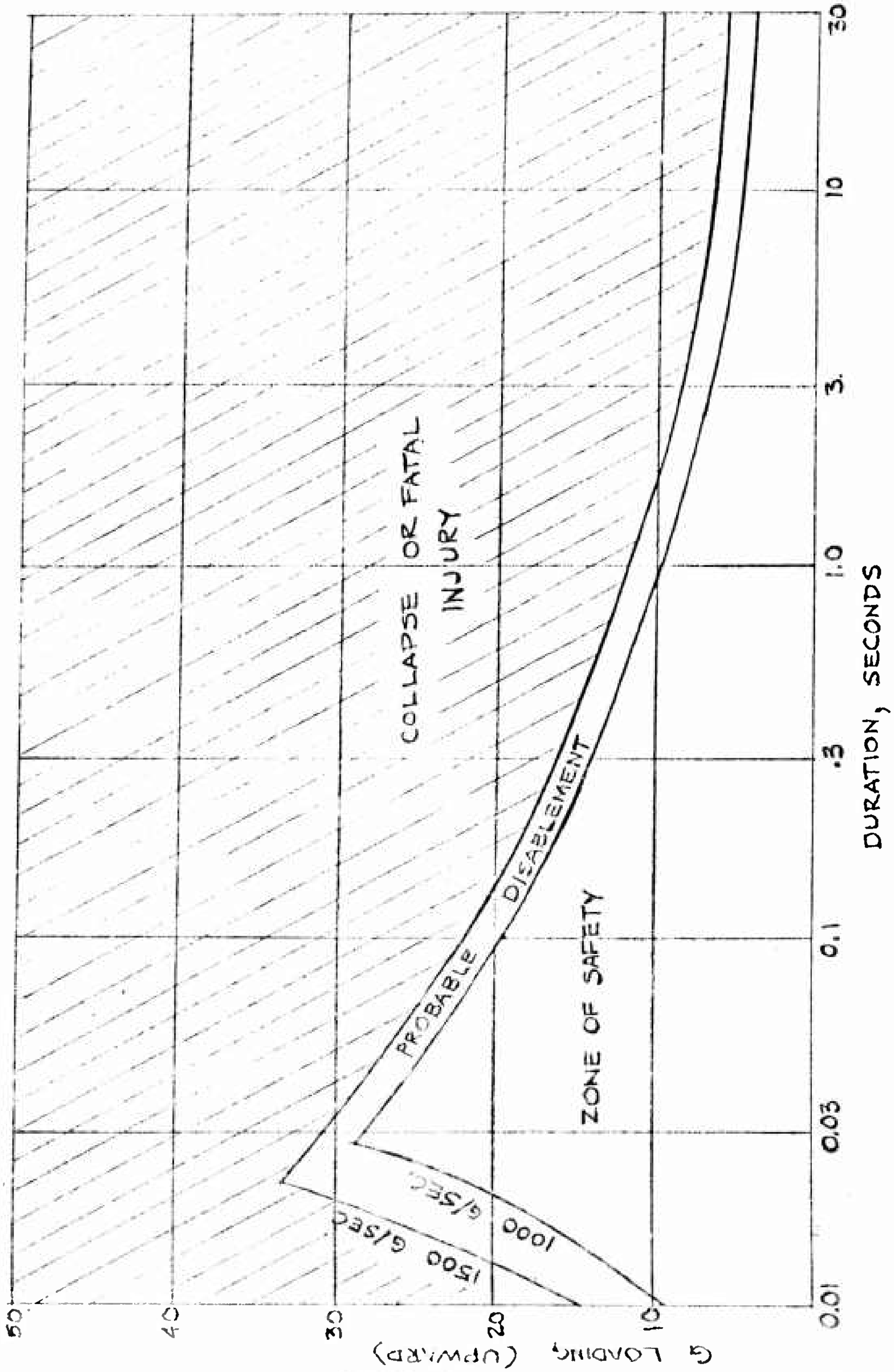


FIGURE 22 - LIMITS OF HUMAN TOLERANCE - SEATED POSITION
(Assuming Vertical G in a Stable System)

tional assault transport to minimize damage and injury in case of an emergency situation.

Aircraft Control.

A stability and control system must be designed for the aircraft for operation in the vertical take-off and landing phases of the flight plan. In the event of a failure during these operations, sufficient control must be retained to successfully maintain the aircraft attitude down to the ground. This point has been considered to be of primary importance in the determination of the stability and control system. An automatic thrust equalization device is considered a necessary part of the system. This would prevent uncontrollable roll forces which might result from a propulsion system failure on one side and would allow adequate control in the emergency.

Aircraft Structure.

The total kinetic energy of the falling airplane must be absorbed at a rate consistent with the safe deceleration values established for the design. This energy must be dissipated by components of the aircraft structure at the required rate. This presents a formidable problem to the designer of the aircraft in that it would be desirable to obtain this characteristic without undue penalty in structural weight.

It is expected that the extended landing gear and the lower part of the fuselage structure will be used as the energy absorbing components. How this will be accomplished was beyond the scope of the present study, but should be the subject of a detailed investigation as soon as possible. The landing gear can be considered to absorb a considerable amount of the energy since it is expressly designed to perform this function. Normally the gear is designed for specific values of sink speed and deceleration desired. Vertical rates of 9 to 12 fps are normal in gear design. It can be expected that the gear can be designed to absorb the same amount of energy in case of an emergency descent. The kinetic energy remaining must be dissipated by deformation, buckling and failure of the tires and landing gear structure and the lower fuselage structure. At this time it is not known whether any radial design changes must be made to do this. Another approach might be the use of special lightweight energy absorbing material placed in the lower fuselage compartments. A considerable amount of energy may also be absorbed by deformation and displacement of the surface upon which the aircraft falls.

Personnel Protection

Simple design features may also be incorporated into the personnel furnishings for the aircraft which will decrease the decelerations to which the crew and passengers will be subjected in case of emergency. The present construction using web and fabric seats appears quite good in that the material can stretch under the loads imposed. This allows restrained motion of the passenger downward during deceleration thereby relieving the peak loads which are imposed. In addition the use of seat structure which will yield under loads greater than the dangerous tolerance levels could serve to maintain the g loadings at a safe value for the occupants. This would also be an excellent field for additional design development.

To summarize, it may be stated that the basic problem of emergency landing arising from power loss during the hovering regime appears soluble. Under the extreme condition assumed for this analysis, the principle problem of crew and passenger safety appears achievable although much basic investigation remains for a satisfactory analysis and solution. In forward flight the aircraft will be safer than current transport aircraft since the power installed for VTOL performance is in the order of three times that required to sustain normal level flight. In event of emergency under these conditions the aircraft can operate as a conventional or STO configuration which is possible with the wheeled landing gear.

VII. WIND TUNNEL PROGRAM

A. Program

Early in the study arrangements were made to conduct a ducted propeller model wind tunnel program at the facilities of the University of Wichita. The program called for a redirection of the work projected for the University under its current ONR contract. Two model ducted propeller units were established for test by the Bell Aerodynamics Section. The design, fabrication and test of the models was undertaken by the University staff.

B. Design

The design work performed by Bell Aircraft personnel was in the nature of technical coordination between the University of Wichita and Bell Aircraft. Basic model layouts were prepared to transmit the necessary dimensional data to the university for the detail design of the test equipment. This was done for both of the test models selected. The section coordinates of the inlet vanes, rotor blades, and exit stators were determined by analysis. This information was converted to very accurate drawings by the Bell loft department to a large scale. Then the sections were reduced photographically to full size and metal templates were produced from the negatives. The metal templates were used by the University in the manufacture of the model blades.

Stress analysis of the critical structural items of the models were performed by the Bell Aircraft Structures Section and the results were used to select the materials needed for the various components of the models.

C. Testing.

Bell Aircraft Aerodynamics personnel were present at the University and assisted in the testing and analysis of the data. Automatic recording oscillograph equipment was loaned to the University by the Bell Aircraft Instrumentation Laboratory. An instrumentation engineer assisted in the installation and calibration of this equipment prior to the start of the tunnel test period.

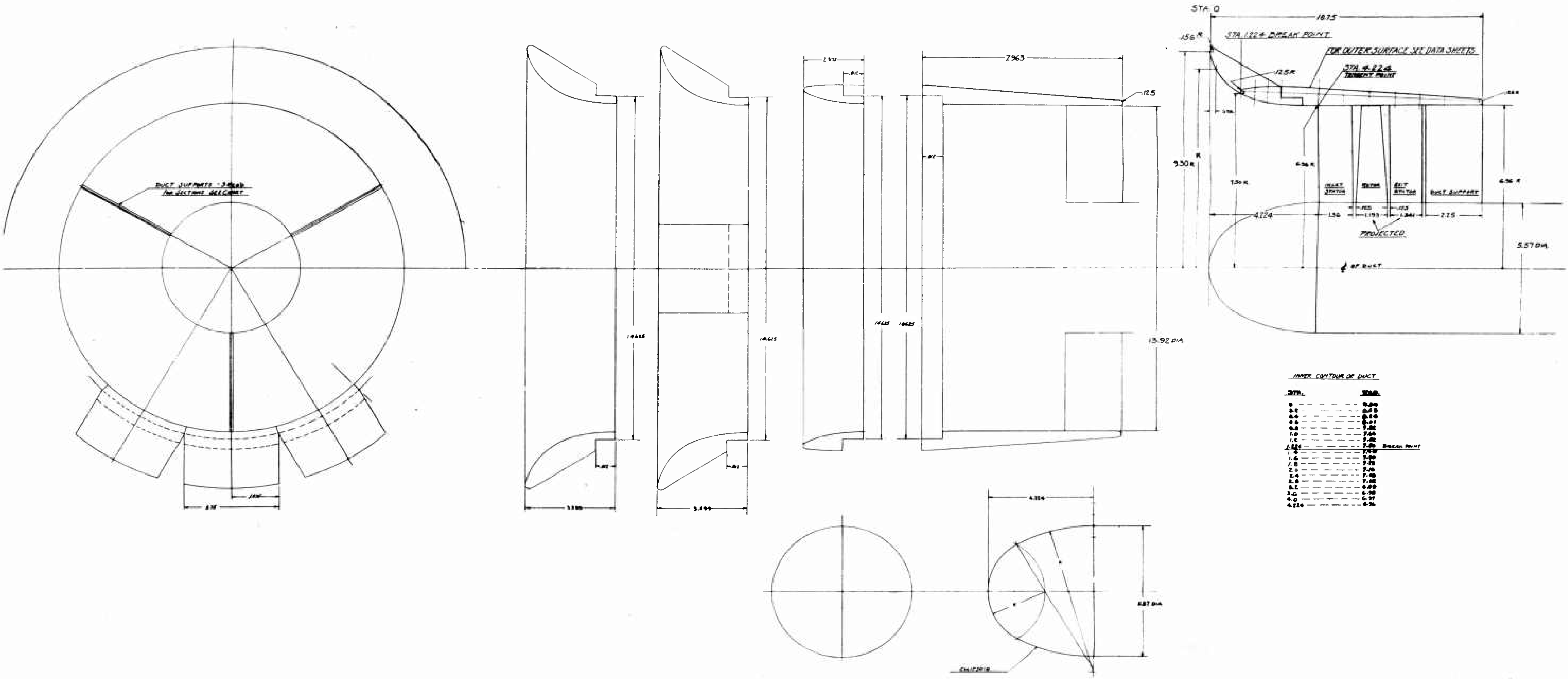


Figure 23. Dwg. No. D181-960-010: Wind Tunnel Model No. 1 Duct Detail

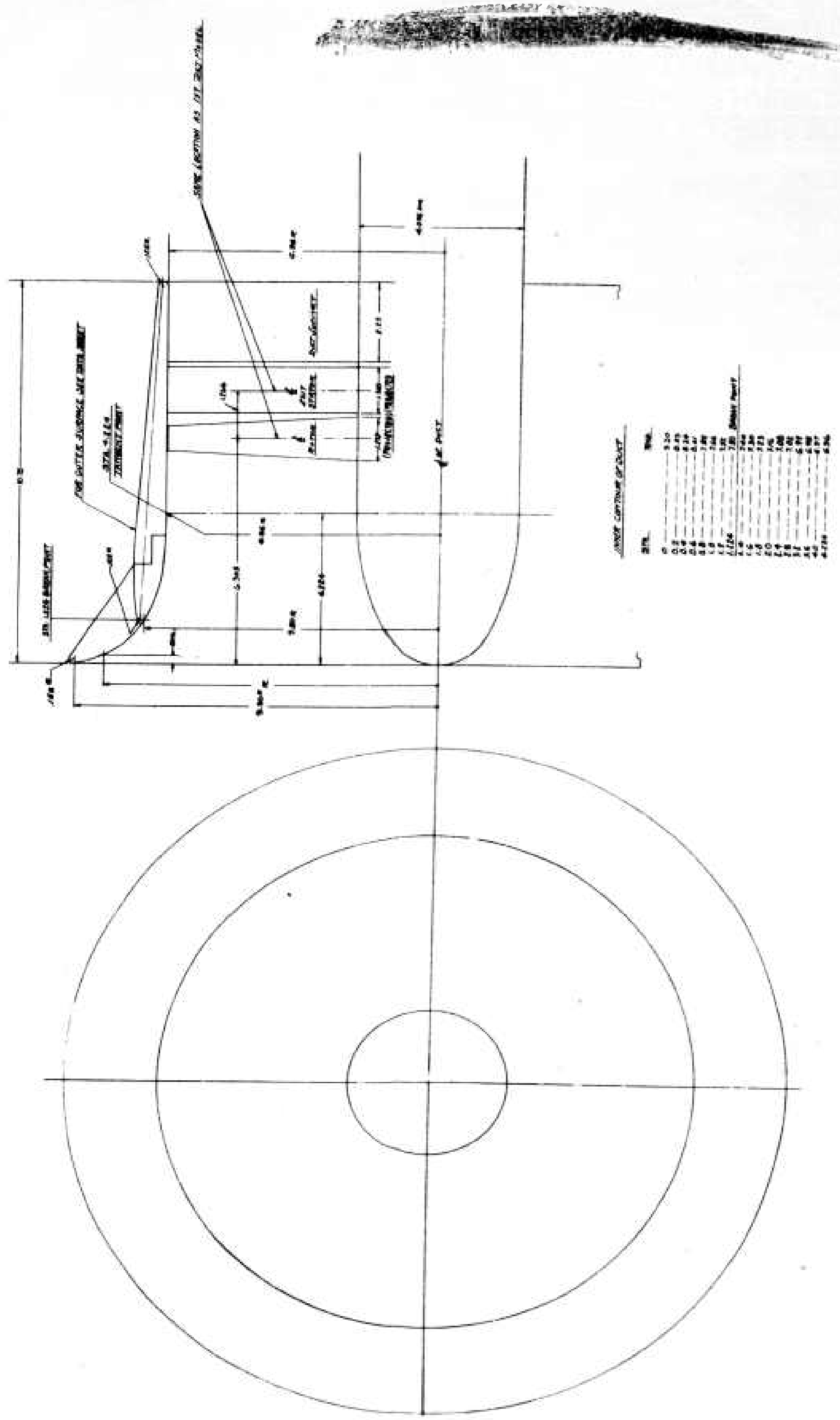


Figure 24. Dwg. No. D181-960-014: Wind Tunnel Model No. 2 Duct Details

VIII. REFERENCES

1. Albert O. Ross and Merle C. Huppert, "Analytical Determination of Effect of Water Injection on Power Output of Turbine-Propeller Engine" NACA TN 3403, dated March 1955.

2. Bell Aircraft Corporation, "Ducted Propeller Assault Transport Study. Duct and Propeller Analysis" D181-945-006, dated 15 May, 1956

3. Rand Corporation, "Capabilities and Operating Costs of Possible Future Transport Airplane" Rand R-249, dated September 1954

4. Bell Aircraft Corporation, "Ducted Propeller Assault Transport Study. Performance" D181-945-004, dated 15 May 1956

5. Bell Aircraft Corporation, "Ducted Propeller Assault Transport Study. Preliminary Structural Analysis" D181-945-007, dated 15 May 1956

6. J. W. Goodrich, "Escape from High Performance Aircraft" WADC TR 56-7 dated 9 January 1956

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